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Engineering
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April, 1941

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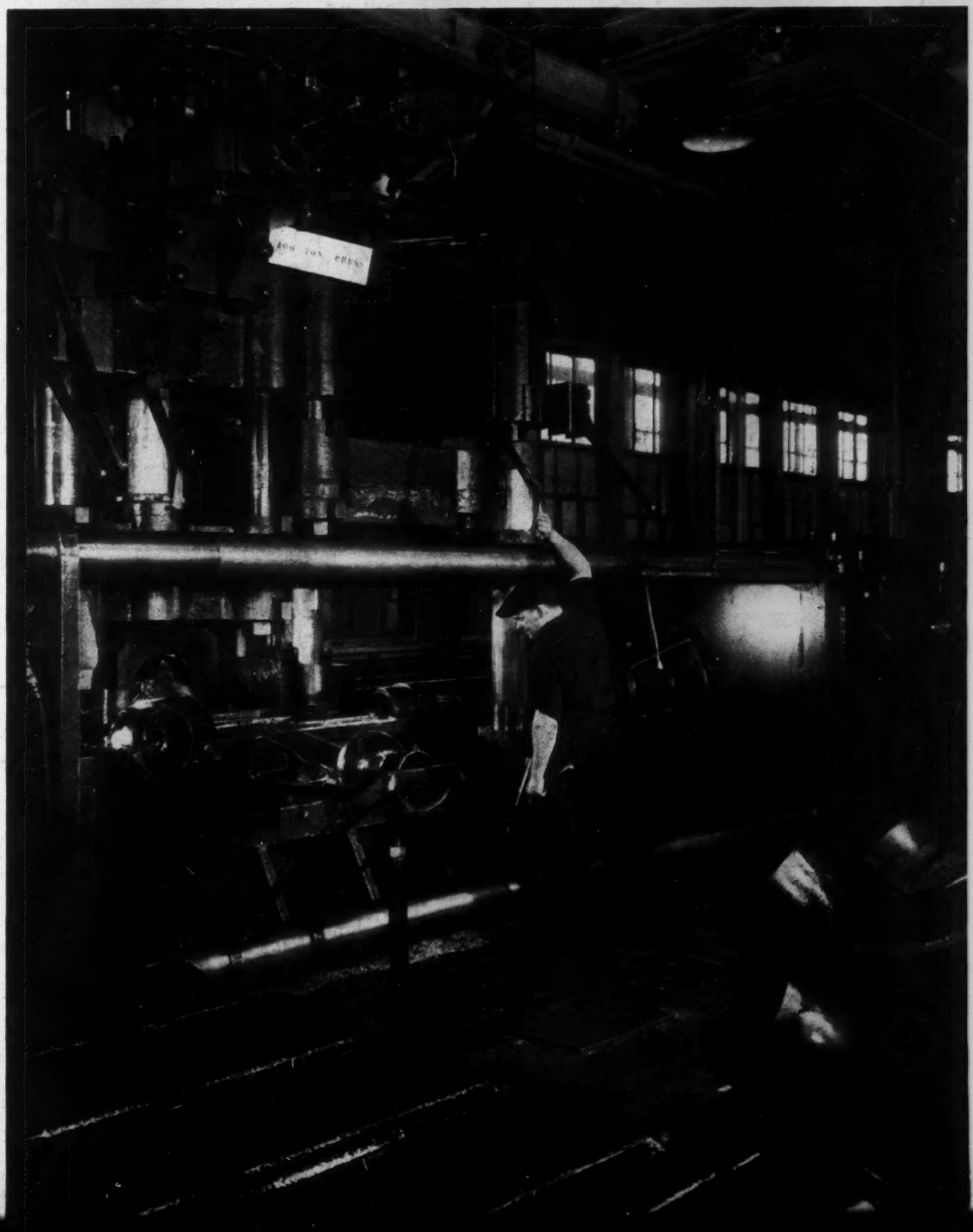

HAT DOES the new STM specification for factory made welding fittings mean to purchasers and users of this product? J. J. Winter explains the significance of A234-40T in his discussion of its requirements and background, pp. 209-216. . . . Pressing welding elbows from seamless steel pipe is shown at right

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Journal Section
The American
Society of Heating and
Ventilating Engineers

How Texrope Helps Air-Condition United Air Lines $300,000 Office Building

CAPTAIN JACK KNIGHT, FAMOUS United Air Lines pilot, inspects Texrope-driven air-conditioning equipment in the general office building. Architects—Albert Kahn Associates. Builder—Warren B. Ewer.

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The Editor's Pages

WAR DEPARTMENT TELLS PROGRESS OF EMERGENCY CONSTRUCTION PROGRAM

The war department announced March 6 that 64 per cent of the projects in the temporary emergency construction program, under the direction of the construction division, office of the quartermaster general, were on or ahead of schedule and that 8 per cent of the projects had been completed. Rapid improvement in the status of the projects had been made within the two months preceding that date, despite the generally unfavorable building conditions during the winter.

Exceptional progress between the week of January 3, 1941, and the week of February 21, 1941, materially advanced the status of the entire construction program of camps, cantonments, ordnance and munitions plants, and other structures being built by the construction division. On January 3, 236 projects were on the program. Of this total, 44 had not been started, 104 were behind schedule, 60 were on schedule, 20 were ahead of schedule and 8 had been completed. On February 21, 239 projects were on the program, of which 13 had not been started, 55 were behind schedule, 129 were on schedule, 24 were ahead of schedule and 18 had been completed.

At the same time, the war department announced that building materials and equipment valued at more than $45,000,000 had been purchased by the centralized procurement office of the construction division, office of the quartermaster general in Washington, D. C., for use in the temporary emergency construction program for defense.

Improvements in heating equipment for camps and cantonments over previous methods are represented in the expenditures for boilers, warm air furnaces and tent heaters. Three types of steam boilers had been purchased, at a total cost of $1,308,414.10, for providing central heat for hospitals and other types of group construction, and steam for the operation of laundries and of kitchens in cafeteria type messes. Purchases of warm air furnaces, one of which is installed in each 63 man, cantonment type barracks, amounted to $3,360,767.38, while those for gas fired tent heaters amounted to $803,948.29.

The individual furnaces in the frame barracks are equipped with thermostats and blowers for the regulation and distribution of warm air throughout all portions of the two story dormitories. In the hot months the blower systems may be operated for the purpose of providing better ventilation and circulation of air.

The centralized procurement office in the construction division at Washington began functioning on September 11, 1940. Following is a list of boilers and furnaces for camps and cantonments it has bought between that date and February 11. These awards do not include any of those made in the field, nor those for other types of supplies purchased by the centralized procurement office.

Boilers and Accessories	Quantity	Cost
Boilers (low pressure)	182	$129,420.85
Boilers (high pressure, fire tube)	108	430,673.25
Boilers (water tube)	83	748,320.00
Feedwater heater	1	2,933.00
Boiler feed pump	1	730.00
Induced draft fan	1	2,563.00
Stack and breeching	1	4,353.00
Furnaces and Tent Heaters		
Furnaces (warm air)	13,812	3,360,767.38
Tent heaters (gas fired)	30,649	803,948.29

MANUFACTURERS REPORT BUSINESS GAINS

■ Westinghouse Electric & Mfg. Co. recorded in 1940 "the greatest expansion in business in its 55 years of existence," the company announced in its annual report issued last month. New records were made in the volume of incoming orders, amount of sales billed, value of unfilled orders, the total payroll for the year and the number of employees at the end of a year. At the same time, the company's increased tax bill represented $427 for each employee in 1940, based on the average number employed during the year, compared with $238 in 1939.

Orders received during 1940 amounted to $400,477,724, an increase of 87 per cent over 1939. Approximately 40 per cent of this 1940 business was orders in connection with the national defense program. Net sales billed amounted to $239,431,447, an increase of 37 per cent over the preceding year. The previous peak was $216,364,588 in 1929.

Unfilled orders at December 31, 1940, were $223,685,737, up 216 per cent over 1939. Net income for the year was $18,985,428, an increase of 37 per cent over 1939.

■ A net profit in 1940 of $526,628, the largest income in any year since the formation of Carrier Corp., was announced last month by President J. I. Lyle. This compares with a profit of $18,788 in 1939. Income before federal taxes equaled $1.95 per share and afterwards $1.34 per share. Total taxes paid or provided for in 1940 were $448,188.

Orders booked during the year were approximately 14 per cent greater than in 1939 and completed sales for the year were 12 per cent above those for 1939, the official noted. The largest backlog of unfilled orders in the company's history, amounting to $4,903,000, was carried over into 1941.

Orders booked for standard prod-

ucts since January 1 are double those for the same period in 1940. In addition to the orders for standard products, this company has orders for special defense work from the government.

As factors in contributing to the improved showing, Mr. Lyle listed "the greatly increased use of centrifugal refrigerating machines in the production of synthetic products and in blast furnaces; a greater volume of manufactured products as distinguished from completely installed contracts; and closer collaboration with architects, consulting engineers and contractors."

■ According to the 49th annual report of General Electric Co., orders received in 1940 totaled $654,189,642 as compared to $360,748,386 in 1939. Net sales billed were $411,938,259 last year, and for the preceding year the figure was $304,680,270. Net income in 1940 was $56,241,083 as against $41,235,644 in '39. The volume of new business booked in 1940 was greater than that for any previous year in the company's history. This resulted partly from the unusual demand for equipment for defense purposes (for which orders amounting to approximately $250,000,000 were received) and partly to an increase in regular commercial business.

FINANCIAL STATISTICS FOR AIR CONDITIONING FIRMS GIVEN BY FEDERAL TRADE COMMISSION

A report on Refrigeration Equipment and Air Conditioning Unit Manufacturing Corporations, in the Federal Trade Commission's project for the collection of annual financial reports from a large number of industrial corporations operating in many of the principal industries of the United States, was issued last month.

The corporations whose reports are combined represent five of the more important concerns in this industry from the standpoint of investment and value of goods sold. The data are shown in combined form and in a manner that does not identify any individual corporation.

The classification of *refrigeration machinery and air conditioning unit manufacturing corporations,* as used, refers to corporations that are primarily engaged in the manufacture of domestic and commercial refrigerators, commercial and industrial ice and refrigerating machinery, cooling systems and air conditioning units. The preliminary report of the bureau of the census for 1939 shows that the combined *value of products for refrigerators, domestic (mechanical and absorption), refrigeration machinery and equipment and complete air conditioning units,* on an establishment basis amounted to $278,645,540 for that year. The five corporations included in this survey reported consolidated sales for the year aggregating $54,597,303, or 19.6 per cent of the total value of products reported by the bureau of the census for 1939.

Of the total sales, $51,367,752, or 94.1 per cent, represented domestic sales, and $3,229,551, or 5.9 per cent, export and foreign sales.

The combined net income (before deduction of interest on long term borrowings and income taxes) on the average total capital of $44,012,807, employed by the five corporations in 1939, was $4,632,735, or a rate of return of 10.5 per cent. This average rate of return represented individual rates of return for the five corporations ranging from a profit of 1.1 per cent to 24.6 per cent. Two of the five corporations had rates of return higher than the average, and their rates were 16.2 per cent and 24.6 per cent. The remaining three corporations had rates of return lower than the average, and their rates were 1.1, 2.8 and 6.6 per cent.

The net income on the average corporate net worth investment or stockholders' equity, after provisions for income taxes, amounted to $3,332,643, and this was a return of 9.4 per cent on the stockholders' investment. The range in rates of return for individual corporations on this basis was from a loss of 2.0 per cent to a profit of 20.7 per cent.

The five corporations realized a net income, after provisions for the payment of income taxes, amounting to $3,332,643 for 1939. The cash dividends paid, or accrued, in 1939 on preferred shares amounted to $253,056, and on the common shares to $2,546,718. The cash dividends paid during the year represented a return of approximately 7.9 per cent to the stockholders on the average ledger value (not market value) of their equity of $35,324,416.

The 1939 operating ratios of the five corporations show that the total cost of goods sold (exclusive of taxes, social security and pension fund payments, selling expenses, administrative and general office expenses, etc.) represented 72.7 cents on every dollar of sales. Of the total cost of goods sold, raw materials represented 33.9 per cent of sales; production wages and salaries, 19.0 per cent; other costs and expenses (not listed under *expenses*), 8.8 per cent; depreciation and obsolescence applying to production facilities, 2.1 per cent; and finished goods purchased for resale, 8.9 per cent. The gross margin on sales was 27.3 cents on each dollar of sales.

The total of items listed as expenses represented 19.6 per cent of the total sales. Of the total expenses, selling expenses represented 10.3 per cent of the sales; advertising, 3.4 per cent; administrative and general office expenses, 2.9 per cent; all taxes (except income taxes and social security payments), 0.9 per cent; all social security and pension fund payments, 1.1 per cent (ratio here is to sales dollar and not payrolls); and research and development expense, 1.0 per cent. After deduction of the items listed as expenses together with provisions for uncollectible accounts of 0.4 per cent from the gross margin on sales, plus other operating revenue of 0.4 per cent, there remained a net profit from manufacturing and trading of 7.7 cents from every dollar of sales.

The total combined inventories of the five corporations amounted to $12,793,495 at the beginning of 1939, as compared with $11,969,711 at the end of 1939, or a decrease of 6.4 per cent.

HEADS NAFM

Edgar F. Wendt, president of Buffalo Forge Co., was elected president of the National Association of Fan Manufacturers at the NAFM annual meeting in Detroit. E. Szekely, vice-president and general manager of Bayley Blower Co., was named vice-president, and L. O. Monroe secretary-treasurer.

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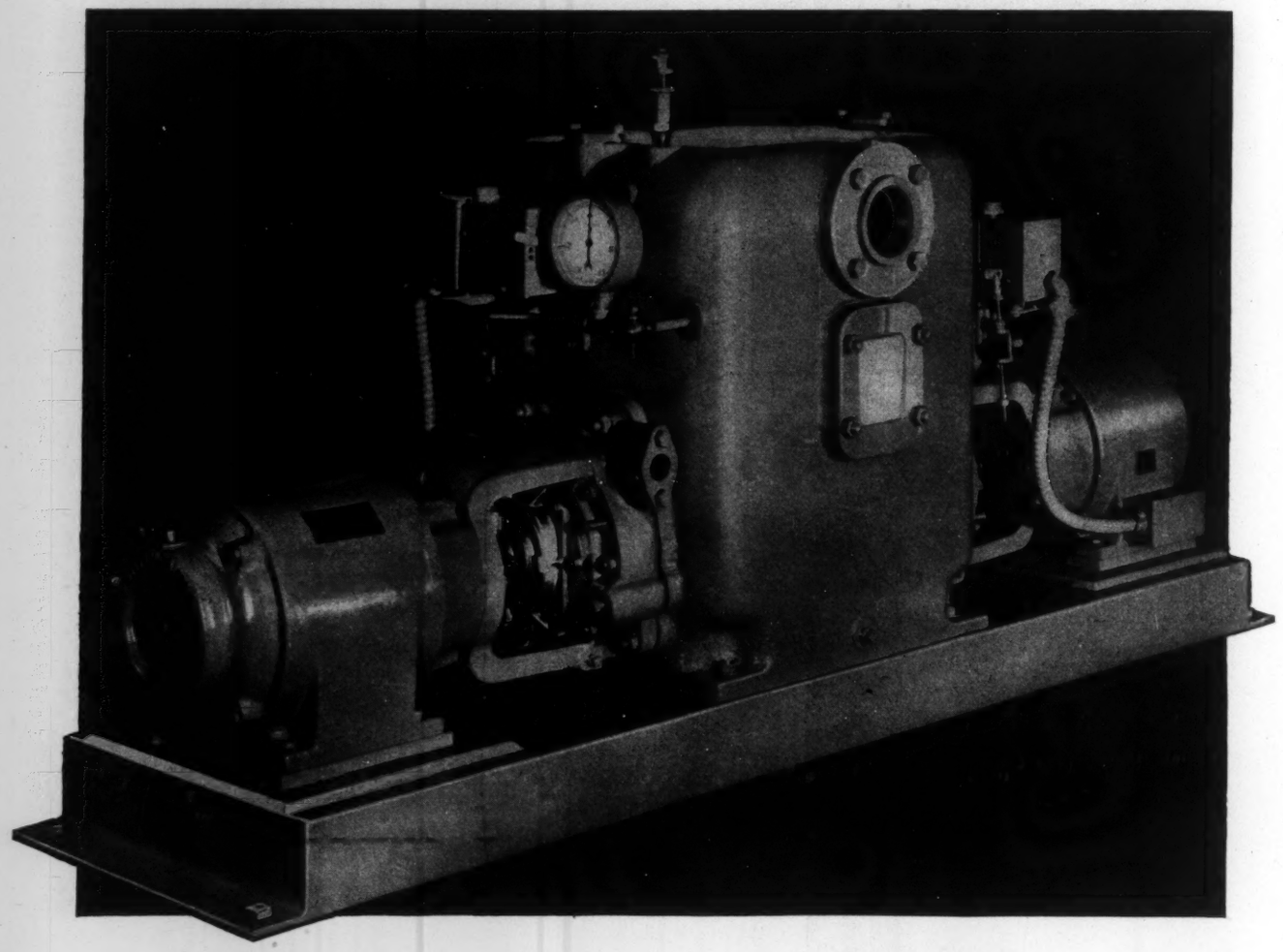

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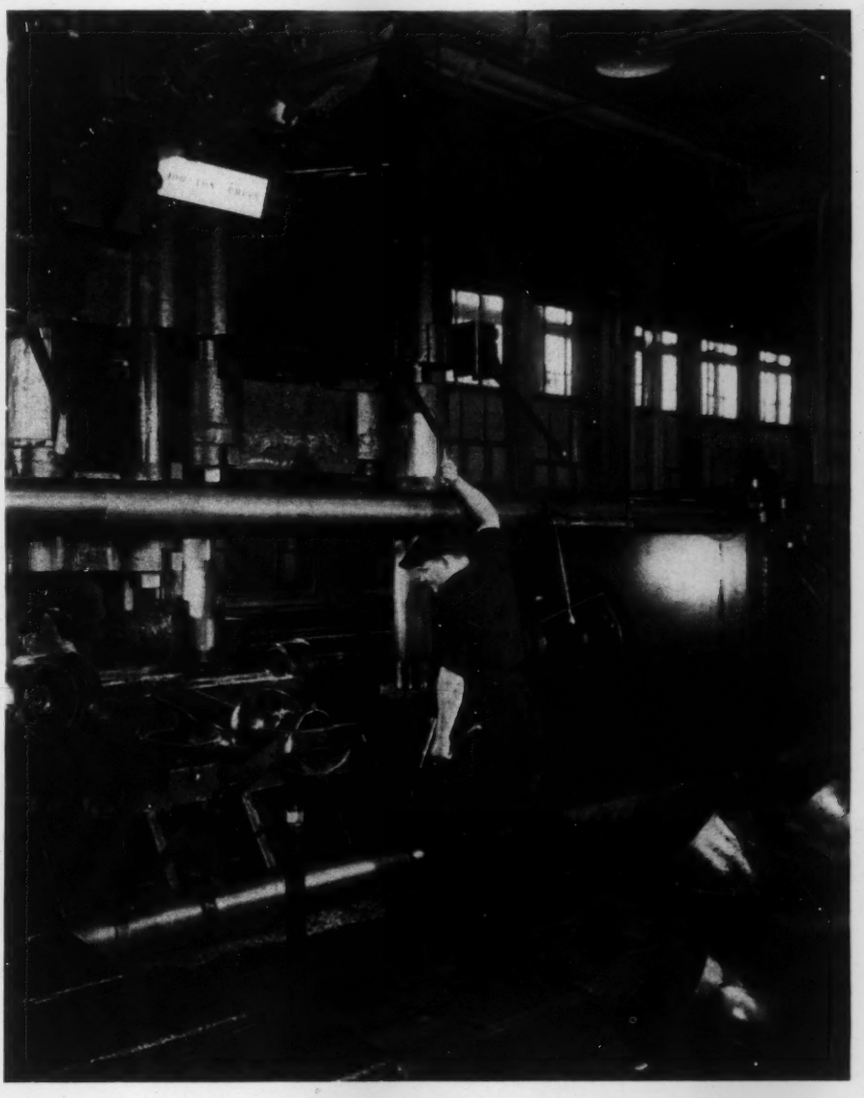


Fig. 1—Pressing welding elbows from seamless steel pipe. Subsequent to this cold forming operation the elbows are heat treated

STEELS for Welding Fittings

J. J. Kanter* Discusses New ASTM Spec

SUMMARY—The usefulness of the new ASTM tentative specification for welding fittings, A234-40T, may not be fully apparent at first glance to the purchaser of welding fittings. The purchaser may perhaps be puzzled as to the distinct purpose for which such a materials specification is needed. The question may be raised as to why simple reference in ASA B16.9 or B16.11, the dimensional standards, to the approved ASTM standards for pipe, plate and billet is not sufficient. Why must this new number A234-40T be carried along in with all of the others? . . . The simplest and briefest reply to this question is that A234-40T covers the quality of the finished product and permits the purchaser to take advantage of the various fabrication methods. The type and form of the material with which the manufacturer starts is so varied that a specification so cast enables the user to take advantage of the available material with a minimum of different specifications. Thus, by using A234-40T for the material designation for wrought welding fittings, the purchaser can dispense with choosing among the detailed requirements of a number of ASTM specifications

THE standardization of factory made welding fittings confronts the piping industry with an almost unique set of requirements for the materials specifications. The proposed American Standard B16.9 for Butt Welding Fittings, discussed by Sabin Crocker in the January, 1940, HPAC, was developed by the American Standards Association and covers complete dimensional specifications, making reference to new tentative specifications which have been published by the American Society for Testing Materials covering welding grades of steel. Formulations of further standards governing socket fitting dimensions are in project.

The undertaking of subgroup 6, on welding fittings of subcommittee 3 of ASA sectional committee B16 in bringing together the various manufacturers of welding fittings from their diverse lines to a common dimensional standard, although requiring many compromises and necessitating much costly retooling, stands as a signal achievement in standardization procedure. Settling upon the dimensions for welding fittings, however, was but one part of the standardization task. Uniform quality of steel was another problem upon which ASA sectional committee B16 asked the help of the American Society for Testing Materials, whose committee A-1 on steel has been engaged for several years, as one of its many responsibilities, with the problems of specifications for steels to be used in welding operations.

Many Processes Used

The problem of specifying the quality of steel for good weldability is complicated by the fact that a number of totally different methods and processes of fabrication are in use. The basic materials used may be either pipe, tubes, plate, strip, blooms, billets, slabs, bars or castings, while the method of manufacture may involve forging or shaping operations by either hammering, pressing, piercing, rolling, extruding, upsetting, forge welding, fusion welding or founding. Some fittings are made using combinations of

*Chairman, section on welding fittings of subcommittee XXII, ASTM committee A-1 on steel, and research metallurgist, Crane Co.

these operations. Thus, it may be appreciated that the steels from which fittings are manufactured are purchased under a number of ASTM specifications covering different steel products of various carbon and alloy grades.

A welding fitting is in itself a definite product for which certain physical properties and test requirements are desired. Heat treatments subsequent to forming operations are necessary in many instances. The type of test which might be required for the basic material is not necessarily a test pertinent to the quality of the finished fitting. Hydrostatic bursting test of a finished fitting conveys more assurance of quality than would a tensile test made upon the unfabricated steel used in its manufacture, although not made mandatory in specification A234-40T. Definite provisions for workmanship, finish, marking and inspection of a highly specialized nature must be set for a factory made fitting to be placed in a stock bin, which provisions are not to be found in various specifications which have been set for the steels used in their manufacture.

Committee Organization

The problem of metallurgically describing the fittings in ASA B16.9 or B16.11 by cross reference to ASTM specifications fell under the jurisdiction of subcommittee XXII, constituted to handle specification matters involving steel piping, fittings, valves, flanges and bolting for service at elevated temperatures. Subcommittee XXII functions through several sections which separately consider such matters dealing with pipe, castings, forgings, bolts and nuts, and welding fittings. At the time that subcommittee XXII received the assignment of recommending specifications for welding fittings materials, the job was referred to the section on forging. After a cursory consideration of the problem and the realization that the recommendation of adequate specifications for welding fittings would require not only consideration of forging steels suitable for elevated temperature uses, but also liaison action with the section on pipe and the section on castings, as well as other subcommittees of committee A1 outside the scope of subcommittee XXII, it was recommended that a new section on welding fittings be organized to formulate materials recommendations wanted by ASA sectional committee B16, subgroup G.

The section on welding fittings was appointed by subcommittee XXII and held a series of meetings to study the materials requirements for the various types and brands of welding fittings being manufactured. It soon became apparent to this committee that a new specification covering wrought carbon steel and carbon molybdenum steel welding fittings would have to be written. As already intimated, a number of the specific product requirements for welding fittings as to metallurgy, inspection and identification are not to be found in the ASTM specifications covering the various steel products from which fittings are fabricated.

A survey among the various manufacturers showed that fittings made under ASA B16.9 or B16.11 involved 11 grades of steel covered in eight ASTM specifications. To undertake to have all of these materials specifications revised or ex-

TABLE I.—CHEMICAL REQUIREMENTS.

Type of Material	A.S.T.M. Designation[a]	Identification Symbol	Carbon, per cent	Manganese, per cent	Phosphorus, max., per cent	Sulfur, max., per cent	Silicon, per cent	Molybdenum, per cent
Seamless Steel Pipe:								
Carbon steels	A 106, Grade A	WPA	0.25 max.	0.30 to 0.60	0.04	0.06	[b]	.....
	A 106, Grade B	WPB	0.35 max.	0.35 to 1.00	0.04	0.06	0.10 min.	.....
Carbon-molybdenum steels	A 206	WP1	0.10 to 0.20	0.30 to 0.60	0.04	0.05	0.10 to 0.50	0.45 to 0.65
Rolled Steel Plate or Strips:			Thickness, in. / Carbon, max., per cent		Acid / Basic			
Carbon steels	A 70	WR	up to ¾ 0.25; over ¾ 0.30	0.80 max.	0.05[c] 0.04[c] / 0.04[d] 0.035[d]	0.05[c] / 0.04[d]		.....
	A 89, Grade B	WRA	up to ¾ 0.20; over ¾ 0.22	0.35 to 0.60	0.06[c] 0.04[c] / 0.04[d] 0.035[d]	0.05[c] / 0.04[d]		.....
	A 212, Grade A	WRB	up to 1 0.28; 1 to 2 0.31; over 2 to 4½ 0.33	0.90 max.	0.04[c] / 0.035[d]	0.05[c] / 0.04[d]	0.15 to 0.30	.....
Carbon-molybdenum steels	A 204, Grade A	WR1A	up to 1 0.18; 1 to 2 0.21; over 2 to 4 0.23; over 4 to 6 0.25	0.50 to 0.90	0.04[c] / 0.035[d]	0.05[c] / 0.04[d]	0.15 to 0.30	0.40 to 0.60
	A 204, Grade B	WR1B	up to 1 0.20; 1 to 2 0.23; over 2 to 4 0.25; over 4 to 6 0.27	0.50 to 0.90	0.04[c] / 0.035[d]	0.05[c] / 0.04[d]	0.15 to 0.30	0.40 to 0.60
Forging Blooms and Billets:								
Carbon steels	A 105, Grades I and II	WF	[e]	[e]	0.05	0.05	[b]	.....
Slab or Bars:								
Carbon-molybdenum steels	A 182, Grade F1	WF1	0.35 max.	0.30 to 0.80	0.04	0.05	0.20 to 0.50	0.40 to 0.60

[a] These designations are given only for cross-reference to the respective chemical compositions and refer to the following specifications of the American Society for Testing Materials, appearing in the 1939 Book of A.S.T.M. Standards, Part I, and Supplements thereto.
Standard Specifications for:
Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 - 40)
Carbon-Steel Plates for Stationary Boilers and Other Pressure Vessels (A 70 - 39)
Low Tensile Strength Carbon-Steel Plates of Flange and Firebox Qualities (A 89 - 39)
High Tensile Strength Carbon-Silicon Steel Plates for Boilers and Other Pressure Vessels (Plates 4½ in. and under in Thickness) (A 212 - 39)
Molybdenum-Steel Plates for Boilers and Other Pressure Vessels (A 204 - 39)
Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 - 40)
Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for Service at Temperatures from 750 to 1100 F. (A 182 - 40)
Tentative Specifications for Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F. (A 206 - 40 T).
[b] This steel shall be silicon-killed when so specified in the order.
[c] Flange grade.
[d] Firebox grade.
[e] The carbon and manganese contents of this steel shall be a matter of agreement between the manufacturer and the purchaser, but the contents for this welding steel shall not exceed 0.35 per cent and 0.90 per cent, respectively.

tended to provide for the special materials requirements of welding fittings would have been an endless task. The specialized field of application for wrought welding fittings would not have warranted the extension of all the specifications covering the pipe, plate or billet used for the fabrication of this product, to cover its detailed requirements.

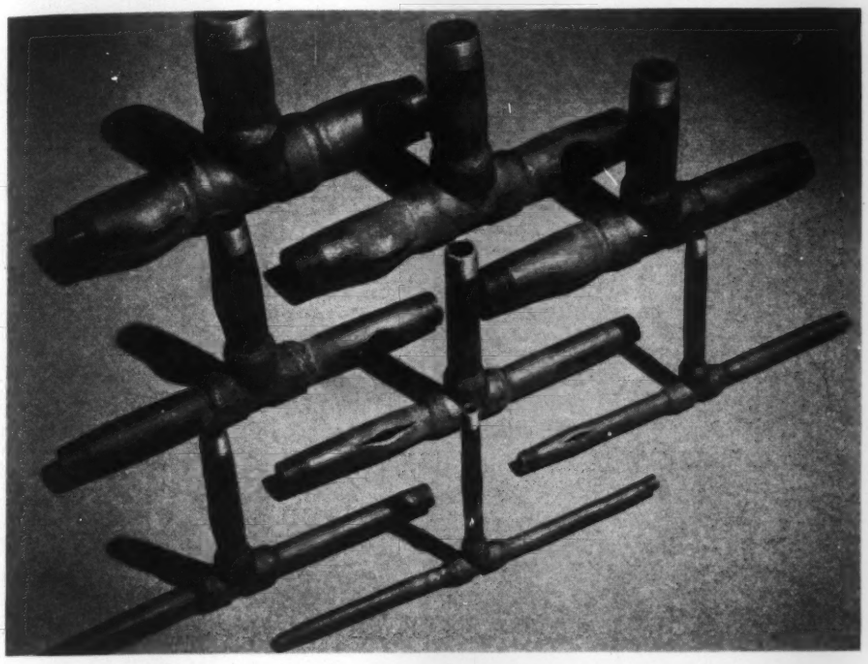


Fig. 2—A group of typical assemblies, made with welding tees, tested to destruction under hydrostatic pressure

New Spec Drafted

Thus, it was considered most expedient that a new specification covering the product, wrought welding fittings, be drafted by the ASTM. Such a specification has been agreed upon by the various manufacturers and consumers represented on the interested committee in ASTM and has recently been published as tentative specification A234-40T under the title Factory Made Wrought Carbon Steel and Carbon Molybdenum Steel Welding Fittings by the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa. The term *welding fittings* as used in A234-40T applies to butt welding or socket end parts such as 45 and 90 deg elbows, 180 deg return bends, caps, reducers, lapped joint stub ends and other types covered by the American Standards for Welding Fittings.

The scope of specification A234-40T does not include fittings made of cast steel, but refers to two other ASTM specifications, A216 and A217, which cover welding grades of pressure castings intended for high temperature service. These castings specifications do cover all of the special testing and marking provisions necessary to cast steel welding fittings. To have included castings in A234-40T would have been needless repetition; thus in ASA B16.9, the butt welding fitting standard, and ASA B16.11, the socket welding fitting standard which will soon be available, direct reference is made to A216 and A217. All wrought steel materials are covered by reference to the one number—A234-40T. Weldable steel castings under A216 and A217 are guaranteed through a number of critical provisions. On chemical composition, not only are the carbon contents restricted to the desirable ranges for good welding practice, but definite limits have been set for alloy contents such as manganese, silicon, copper, nickel and chromium, which are known to influence weldability of steel castings. The testing and inspection of requirements of these specifications should adequately safeguard the interest of the purchaser buying cast welding fittings which comply.

Chemical Requirements

Table I of specification A234-40T (reprinted here by permission of the ASTM) lists the chemical requirements for wrought welding fittings. These compositions are identical with those found in the ASTM specifications for the corresponding types of material, but are assigned symbols in the table to uniquely identify them with A234-40T. These identification symbols have been chosen so as to be consistent with the system of marking symbols which have been set up in the ASTM specifications covering high temperature and high pressure piping materials. The ASTM designations are given for cross reference only and in no way imply that requirements other than chemical composition apply to the finished product of A234-40T.

The compositions covered in Table I are all recognized as weldable grades of steel and are drawn from those ASTM steel specifications which, during the past several years, have either been drafted or revised in the interest of defining steels which could be satisfactorily welded under ordinary conditions. In this sense, certain of the specifications cross referenced in Table I may already embrace certain types of welding fittings, as for instance A105-40, which was amended recently to provide for a 0.35 per cent maximum carbon, to permit the use of steel under that designation in welding neck flanges. Neither specification A105 nor specification A182 for forged flanges, however, embraces all of the special requirements necessary for the various types of drop forged or pressed fittings made from the blooms, billets, slabs or bars which may be obtained under their designations. Neither could finished fittings be purchased under merely the pipe steel designations A106 or A206, nor to the plate or strip designations A70, A89, A212 or A204. Thus, while the chemical requirements of these various ASTM specifications may be cross referenced as weldable steel so far as *chemical requirements* are concerned, A234-40T disclaims their other provisions as applying to welding fittings and independently covers the additional materials provisions considered to be essential for welding fittings.

Heat Treatment, Etc.

The heat treatments, physical tests or finishes necessary for pipe or plate intended for use as such become superfluous when the material is intended for reshaping in an operation which necessitates the heat treatment, physical testing or finish to be established subsequent to fabrication. Thus, compositions of materials may be purchased under the essential requirements as set up in A234-40T in some instances at a considerable economy. The composition and physical properties of the finished fitting are the criteria of quality and serviceability in which the purchaser of the fitting is interested, while the burden of procuring materials which will satisfactorily "shape up" into an article of the quality which the purchaser needs is largely a problem for the manufacturer.

Specification A234-40T, being a set of quality requirements in finished steel products, therefore has been set up in such a way as to govern only the characteristics of raw material pertinent to the purchaser's requirements. These characteristics include (among other things) process of manufacture, whether open hearth or electric furnace, chemical composition, and, in the case where fittings are intended for high temperature service above 750 F, the steelmaker's "killing" practice.

It has been demonstrated that good high temperature creep strength is best insured in steels which have been silicon killed. Aware of the fact that no ready acceptance test for good high temperature qualities can be used in routine verification of steels entering high temperature service, A234-40T allows for the specification upon order of silicon killed steel for fittings to be used in service at temperatures over 750 F. Recognizing that for some purposes steel might be required for welding fittings having limits upon elements not covered in Table I, such cases are stated to be a matter for agreement between manufacturer and purchaser. The chemical requirements which have been established as mandatory under A234-40T cover steels which manufacturing experience can use for making stock lines of welding fittings.

Highly Alloyed Steels

Table I of A234-40T at present covers no other type of alloy steel for standard welding fitting than the carbon molybdenum type. The committee recognized that other types of alloy steel are in use which in the future may be employed to a greater extent than at present. The precautions regarding manufacture, weldability, heat treatment and testing necessary for more highly alloyed steels are quite different from the provision made in A234-40T. Thus it is anticipated that when the need for standardization of higher alloy steel welding fittings becomes apparent, the ASTM committee will be charged with the task of developing independent specifications covering such fitting materials.

Manufacturing Operations

A wide range of manufacturing operations for making welding fittings is recognized in A234-40T, which provides that forging or shaping operations may be performed by hammering, pressing, piercing, rolling, extruding, upsetting, forge welding or fusion welding, or by a combination of these operations. The forming procedure is required to be so applied that it will not produce injurious defects in the fittings.

It is the intent to admit under these specifications any fitting except a cast fitting, regardless of method of manufacture, which fulfills the standard requirements as to suitability and quality. Manufacturing operations necessitating joining by fusion welding are required in A234-40T to be made in accordance with the code for pressure piping (ASA B31.1), section 6, covering fabrication details. Chapt. 4 of the latest revision of these rules gives precise directions for the making of fusion welded joints. These rules cover backing rings, fillet welds, seal welds, welding procedure, preheating practice, stress relieving treatments and procedure and operator qualifications.

The heat treatment accorded factory made steel welding fittings is a matter dependent upon the forming procedure and the particular grade of steel used. In the case where a carbon steel fitting is hot finished in either a bending or forging process no further treatment may be necessary, provided the finishing temperature be within the range of 1150 to 1650 F provided in A234-40T.

Forming operations finished in this range of temperature will leave the carbon steels recognized in Table I in a satisfactorily "stress relieved" condition. Finishing from above 1650 F, however, is likely to leave the steel in an objectionally grain coarsened state with poor ductility and low impact resistance. The provision that carbon steel fittings finished above 1650 F be subsequently normalized safeguards against poor steel structure due to overheating in hot finishing.

The finishing of any metal forming operations at temperatures from 1150 degrees Fahrenheit down to room temperature is regarded in A234-40T as cold finishing and stress relieving by reheating is in all cases required. Welding elbow and return bends fabricated from pipe or tubing by cold pressing operations, unless given the stress relieving heat prescribed in A234-40T, are apt to be lacking in toughness, but through treatment become fully as reliable as any hot formed fitting.

[*A second article will discuss carbon moly fittings, welding operations, testing and certifying, and marking fittings.*]

Shortly after subgroup 6 of the American Standards Association's sectional committee B16 was appointed to formulate dimensional standards for welding fittings, it was recognized that such standards could provide maximum usefulness to industry only if supplemented by suitable materials specifications as already provided for other American standards for flanges, fittings, valves, and pipe. Accordingly, committee B16 invited the American Society for Testing Materials to prepare, through its proper committee, a materials specification to serve as a companion to the projected dimensional standards for welding fittings. The need for this combination was immediately recognized by the ASTM and work was undertaken on ASTM specification A234 concurrently with the development of dimensional standards ASA B16.9 and B16.11.

The underlying reasons for the form of the specification, and the complete discussion of its various provisions as detailed in Mr. Kanter's article, should be helpful to many engineers having occasion to use factory made welding fittings.—Sabin Crocker, chairman, subgroup 6 on welding fittings of ASA sectional committee B16 on standardization of pipe flanges and fittings; senior engineer, engineering division, The Detroit Edison Co.; and member of HPAC's board of consulting and contributing editors.

Gas Fired Units Solve Many INDUSTRIAL HEATING PROBLEMS

W. N. Blinks* Cites Applications of Gas Units for Heating Plants Engaged in Defense Work

SUMMARY—This discussion has been adapted from a paper presented last month at the conference on industrial gas sales of the industrial and commercial gas section of the American Gas Association, which was held in Baltimore. While Mr. Blinks was speaking primarily to men interested in *sales* of gas to industrial and commercial users, his picture of the place of gas fired unit heaters for solving industrial heating problems of many kinds contained a number of points of interest to plant engineers and others who are concerned with selection and purchase of the equipment. . . . As presented here, Mr. Blinks' paper describes a number of applications where gas fired equipment may be used to advantage in the plant, with particular reference to the problems arising from the national defense program, in which so many plants are now in some manner engaged

BIG things are happening today in the industrial space heating picture. Defense plant construction together with expansion of existing facilities, rehabilitation of idle industrial plants, and recognition of the necessity for improved working conditions all combine to create a huge demand for heat.

In industrial work, the "glamour girl" attributes of gas fuel are not very important. The "health and comfort of the wife and kiddies" are not involved. The release from the dirt and drudgery of hand firing would be a useless point to conjure up. The picture of the tired householder beaming at the thermostat while the winds howl outside leaves the plant engineer bored. Dollars-and-cents hard facts form the basis on which plant heating equipment is selected; on this basis, many applications of direct gas unit heating exist regardless of the actual or comparative cost of gas.

Consider the low temperature drying room field. Twelve months in the year such areas must be kept at constant temperatures. During the warmer months, when other heating demands are nil, there are definite economies with gas fired unit heating.

Spring and fall heating of office space is another case in point. Plant offices require heat from 30 to 60 days longer in both seasons. Marked savings through the employment of

*General Gas Light Co.

No floor space is required by the gas fired unit heaters in this machine shop

direct gas heating are often possible. Take into account also the rooms that for one reason or another have to be carried at high temperatures during week-end shutdowns of the plant. Gas unit heaters furnish a practical answer.

Investigate current departmental hours of operation. Many firms, finding a bottle-neck confined to one or two departments, and being unable or unwilling to acquire additional machinery, are running these particular departments 16 and even 24 hr a day. Gas unit heaters provide the ideal pick-up to maintain working temperatures during these added hours.

Improved Working Conditions

Management interest in plant working conditions is definitely on the increase. The most frequent complaint about working conditions is that of inadequate heat. Many times it is a severe headache to officials because the heating system is already overtaxed. It further complicates the problem because such a complaint comes quicker than a shot-gun wedding after the "Old Man" knows the facts. Gas unit heaters give a quickly installed solution. Cold spots can be eliminated fast. Fuel cost is often secondary.

Temporary buildings are mushrooming up these days. Gas unit heaters, with their low installed cost, their high salvage value, and their efficient use of gas often are the answer regardless of the dollars and cents of the rate.

The effects of industrial disease legislation should be studied. Open salamanders are now frowned upon in many factories. Dust collection systems require heated settling tank rooms. Ventilating systems create demand for added outside air intake, and this must be tempered with heat. Gas unit heaters provide the answer in many cases.

Consider the storage of products which must be protected against freezing, or against excess humidity. Packing plants face this problem in both ways. Canned fruits and vegetables cannot be allowed to freeze, nor can they be subject to high relative humidities, because cans rust and labels loosen and fall off. With gas fired unit heaters, temperatures safely above freezing can be economically maintained without attention and with humidity controls tied in low relative humidity can be held through increases of temperature when required.

The plywood industry demands such protection of finished board, and often gets it through gas unit heating with temperature and humidity controls. Plate glass storage calls for humidity control, condensation on polished plate causing serious spotting.

Sugar, salt and other hygroscopic chemicals must be guarded against moisture damage. Gas unit heaters, with proper controls, keep such chemical warehouses safe, without daily attention. Efficient control keeps the fuel cost down to a point where manufactured gas can be used for some such applications.

Higher Plant Temperatures

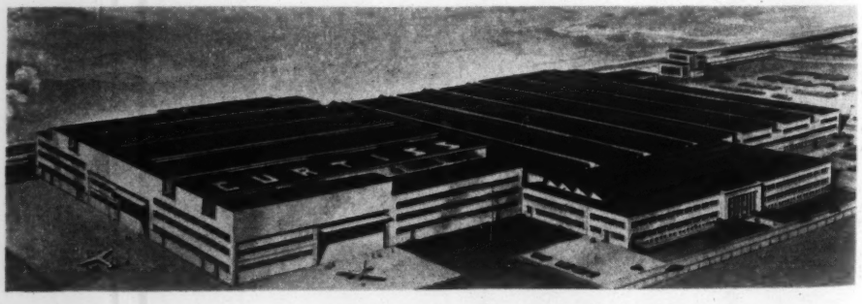
There is an increasing tendency to provide higher working temperatures in factories. The old belief that 50 to 55 F is adequate has been exploded. More and better production will result from 65 to 70 deg controlled temperature. Gas unit heaters will provide this extra 15 to 20 deg at low operating and equipment cost.

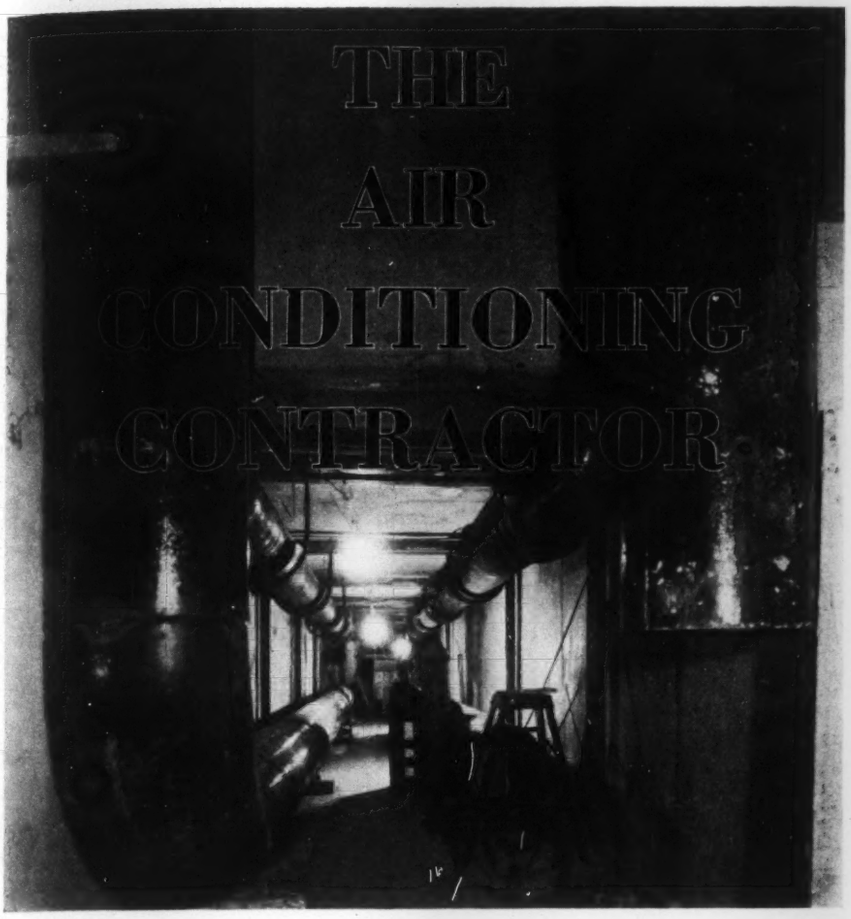
Along this line, controlled temperatures are regarded as absolutely essential in precision processes where tolerances are now measured to one ten-thousandth of an inch. Year 'round air conditioning has already been employed in plants having over a million square feet of floor space. Gas unit heaters are providing the means for handling the winter heating of some such plants, either as duct heaters, or hung in the conventional manner, with outside air intakes attached. There is so little infiltration in such structures that air must be introduced mechanically. What a far cry from the drafty barns of only a few years ago!

The opportunity for direct gas fired unit heating in areas where process heat liberation handles all space heating requirements during working hours should be analyzed. Installation of gas unit heaters to hold the necessary non-working hour temperature can be done at low cost, and with surprisingly low operating figures.

One application which frequently comes up is that of spot heating. A word of caution about it seems advisable. Unit heaters are air heaters. They give a definite temperature rise to all air passed through. If air should be taken into the unit at, say, 20 deg, the delivered air may not, in many cases, be over 80 F at the face of the unit. This is cold air, from a warm air heating standpoint, and becomes a good deal colder a few feet away from the heater. If the air stream is directed at the workmen, the effect is highly unsatisfactory. Care should be exercised in recommending a unit heater for one corner of an unheated shop for this reason.

The new Curtiss-Wright plant being erected at St. Louis, Mo., will be one of the largest aircraft manufacturing plants in the middle west for the mass production of military and naval airplanes. Scheduled for completion in May, it comprises an office and engineering building, with two stories and basement, a factory building with one story and partial basement, a boiler house, a personnel building and an oil house. The factory portion is to be heated by unit heaters and will have roof ventilators for winter and summer ventilation. The office and engineering section is to have hot water heating and the personnel building is to be steam heated. The office section, factory basement and personnel building are to be air conditioned, according to Albert Kahn Associated Architects and Engineers, Inc.





J.M. Sperzel, Buensod-Stacey Air Conditioning, Inc., Tells of Final Steps to Assure Good Job

SUMMARY — Balancing air distribution to assure that it is in accordance with the designer's intentions, making adjustments for unforeseen conditions, painting and stenciling the equipment, instructing the operating force, and observation of performance after the system has been turned over to the owner comprise final steps in the installation of good air conditioning. . . . Mr. Sperzel completes his earlier article on the importance of coördination in installing large air conditioning systems (published in the January, 1941, HPAC) with this discussion of these important final steps

HAVING made certain that the various equipment to condition air is properly insulated and in operating order, there remains that phase of erection devoted to balancing air distribution in accordance with the designer's intention, and attaining the desired relationship of dry bulb temperature and moisture content in each of the respective parts of the system.

Balancing Air Distribution

The process of balancing air distribution requires a thorough survey of air quantities measured at all outlets, coincident with a measurement of static pressure at the entrance to each major supply duct comprising a zone, and under the essential conditions of unrestricted air flow through the distribution system and dehumidifier. Readings taken with an anemometer or direct reading velocity meter at the outlets are examined in relation to specified air quantities, and totaled for each zone for a similar comparison. If construction permits, a check on the sum may be obtained by pitot test. A total summation of air quantities should establish ability of the fan to deliver more air than specified. If this is not the case, it may be necessary to increase the fan speed, other conditions permitting, to obtain the required capacity.

Satisfied that the fan is capable of adequate delivery when the system is unrestricted, all outlets on a single branch are balanced, to deliver a uniform percentage above or below specified capacity through repeated readings and adjustment of louvers behind registers or the insertion of orifice rings in air diffusers. Where the per cent of capacity of one branch differs from another, adjustment of splitters at the connection to the main run proportions the percentage of each branch to a new common value. An identical procedure followed for each zone eventually indicates the need for a reproportioning of air between them. This is accomplished by measuring statics of the zones as balanced, calculating the required static for specified capacity and dampering over capacity zones to provide air for zones below capacity. A pitot tube traverse is performed to verify results. Return and exhaust systems are balanced in a similar manner.

Unforeseen Conditions

Inevitably, certain conditions arise which were not foreseen at the time of planning. Control instruments may not reflect true temperatures because of location or exposure. A new arrangement of partitions or furniture may necessitate a relocation of room thermostats to secure a final control adjustment that is effective. Frequently, seating positions of occupants are arranged to require an adjustment of horizontal and vertical deflecting vanes behind registers to eliminate uncomfortable drafts. The performance of the entire system is scrutinized from the standpoint of safe, quiet and economical operation, complete and responsive temperature and humidity control, and a general room atmosphere that is pleasant to occupants under all reasonable conditions of internal and external load.

Instructing Operating Men

It is the further responsibility of the contractor thoroughly to acquaint and instruct the operating engineer in all matters pertaining to the location, operation and mainte-

Performance of the entire system is scrutinized from the standpoint of safe, quiet and economical operation, complete and responsive temperature and humidity control, and a general room atmosphere that is pleasant to occupants under all reasonable conditions of load

nance of equipment. It is customary to prepare and furnish installation drawings showing the exact arrangement and location of all work as actually installed in the building. Brass tags with countersunk black filled numbers are attached to valves and a chart indicating the numbers, system, function and location of each valve is framed under glass and displayed for the convenience of the engineer. Written operating and maintenance instructions containing replacement parts lists serve as a guide for the future.

The contractor takes pride in finishing equipment in appropriate colors of paint that require greater skill in application than can be generally attributed to average house painters. Certain machined surfaces are cleaned and polished. Signs required by code, and nameplates on manufactured equipment, remain unpainted to provide marks of identification, while piping containing water and steam for various purposes is suitably stenciled. After assisting the owner to secure necessary city permits to operate and maintain refrigeration equipment on the premises, the contractor, in taking leave of the project, can be confident in the ability of the system to provide many comfortable years of good air conditioning.

Can't Forget His Job

The responsibility of the air conditioning contractor, however, does not end in turning over the plant and equipment for operation by the owner's force as he still is morally and financially bound, in addition to the usual contract terms where defective workmanship and materials are guaranteed to be replaced without charge for a period of one year, that the system as designed and installed gives the owner the full measure of satisfaction in the conditions as maintained throughout all seasons of the year.

Naturally, the better planned and installed jobs have the inherent facilities to function under any seasonal conditions of weather and of loading within the spaces conditioned, but still it is necessary to review the functioning in the different kinds of weather that take place throughout the year.

The air conditioning contractor, therefore, cannot forget his job at the time he turns it over to the owner. If he is an experienced contractor his organization will be so planned that the project itself can be placed under the observation of his own men (or by competent men that are chosen by him in remote cities) to make reports on the functioning of the coördinated equipment to insure the successful results that the owner has paid for.

The war department announced March 15 that within five months of the starting date, essential troop housing for over 18,000 men, including hospital facilities and utilities, had been completed at Fort Belvoir, Va., under the direction of the office of the quartermaster general. The project consists of 643 buildings and a 55 building station hospital, complete with central heating plant and enclosed walks connecting the wards and buildings. Heat for the hospital is supplied by a 1000 hp, two boiler plant placed in commission in record time. The boilers were delivered the first week in January before the foundation had been poured for the boiler house. The brick work was finished in 10 days and one boiler, more than sufficient for the needs at that date, was under steam by February 15.

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While fogs can be destroyed by electrical precipitation and by supersonic vibrations, the most promising methods appear to be those which lower the relative humidity of the air sufficiently to cause rapid evaporation of the fog droplets, according to the Industrial Bulletin of Arthur D. Little, Inc. Houghton and Radford of the Massachusetts Institute of Technology have used sprays of concentrated solutions of drying agents like calcium chloride. With the latter salt, they have kept a volume about 1800 ft long, 130 ft wide, and from 30 to 60 ft high free from fog by the expenditure of 85 gpm of saturated solution. The fogs cleared away had speeds up to 16 mph. The cost of drying agent used, assuming a nearby source of calcium chloride solution, would be about $220 per hr. Equipment such as this, with perhaps somewhat larger capacity, might be used to clear the dangerous last hundred feet of descent for a fog blinded airplane landing by use of instruments.

Houghton and Radford estimate that to keep the same volume clear by the use of heat would require the expenditure of about 5000 kw continuously. The difficulty would be not in supplying the necessary energy, but in releasing or transmitting it evenly over such a volume.

THE WATER-AIR CHART

Its Use for Solving Problems Involving the Exchange of Heat Between Air and Water... By William Goodman*

SUMMARY — The water-air chart provides a graphical method by which a great many types of problems dealing with the exchange of heat between air and water can be greatly clarified and conveniently solved for numerical answers. It can be used not only for problems involving the exchange of heat between air and water in spray chambers and coils, but also for problems dealing with the temperature of the spray water in evaporative condensers and spray coolers, and for problems dealing with the surface temperatures of coils. . . . The water-air chart provides a particularly clear picture of the action taking place in air washers, cooling towers and coils. With its aid many difficult problems can readily be visualized and solved. This is particularly true of counterflow problems, otherwise difficult to visualize

IT would hardly seem that so apparently simple a topic as the exchange of heat between air and water would require any great elaboration. Nevertheless, the topic is not nearly so simple as a superficial examination would indicate. There are cases which can be extremely puzzling unless some simple method is available for analyzing them. This is particularly true of problems involving counterflow of air and water, and of problems involving the theoretical final temperature to which air and water can be cooled or heated.

The use of the water-air chart of Fig. 1 provides a graphical method by means of which a great many types of problems dealing with the exchange of heat between air and water can be greatly clarified and conveniently solved for numerical answers. This chart can be used not only for problems involving the exchange of heat between air and water in spray chambers and coils, but also for problems dealing with the temperature of the spray water in evaporative condensers and spray coolers, and for problems dealing with the surface temperatures of coils. In all these types of problems, an equation of the following form is used.

$$N = \frac{h_2 - h_1}{t_{f1} - t_{f2}} \quad \ldots\ldots\ldots\ldots [1]$$

The value of N depends upon the type of problem to which the equation is to be applied. Equations for the value of N for each class of problems are listed in Table 1. The application of these equations for solving problems is discussed later.

Using the Chart

The water-air chart of Fig. 1 is shown in skeleton form in Fig. 2. From this figure it is apparent that Equation 1 is represented by a straight line on the water-air chart. Furthermore, the slope of this straight line depends only upon the value of N. If the value of N and the location of one point on the water-air chart are known, a straight line representing Equation 1 can immediately be drawn. It is this fact which permits the water-air chart to be used for the solution of a great variety of problems involving the exchange of heat between air and water.

The true enthalpy (total heat) of air in any condition can be found either from psychrometric charts, or computed from tables as given in HPAC, January, 1938, pp. 1-7, or HPAC, June, 1939-July, 1940, inclusive. However, for ordinary work, the enthalpy of saturated air corresponding to the wet bulb tem-

Symbols

A = area of outside surface of condensing coil, sq ft.
B = ratio of external to internal surface of coil.
c = humid specific heat of air (c = 0.243 approximately).
c' = specific heat of liquid.
E = efficiency.
f_g = coefficient of heat transfer through air film, Btu per hr per F per sq ft.
f_R = coefficient of heat transfer through liquid film, Btu per hr per F per sq ft.
G = weight of air circulated through condenser, lb per hr.
G' = weight of liquid circulated, lb per lb of dry air.
h = enthalpy of saturated air at wet bulb temperature t'.
N = see Table 1.
s_h = Btu per in. of length.
s_t = degrees Fahrenheit per in. of length.
t_f = temperature of liquid, F.
t' = wet bulb temperature of air, F.
θ = angle for N-line.
U = overall coefficient of heat transmission from condensing refrigerant to spray water for an evaporative condenser, Btu per hr per sq ft per F.
Z = see table on p. 167, March, 1938, HPAC.

Numerical subscripts refer to condition of air or liquid at various points in heat transfer process. For example, subscripts 1 and 2 refer respectively to initial and final conditions of air or liquid.

*Consulting engineer, The Trane Co. Member of HPAC's board of consulting and contributing editors.
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Table 1—Equations for N

Exchange of heat between air and water—parallel or counterflow (Eq. 4)	$N = G' c'$
Evaporative condenser or sprayed cooling coil	
(a) Temperature of spray water (Equation 12)	$N = \frac{UA}{GZ}$
(b) Limiting temperature of spray water (Equation 13)	$N = \frac{cU}{f_g}$
Cooling coils—surface temperatures (Equation 14)	$N = \frac{cf_R}{Bf_g}$

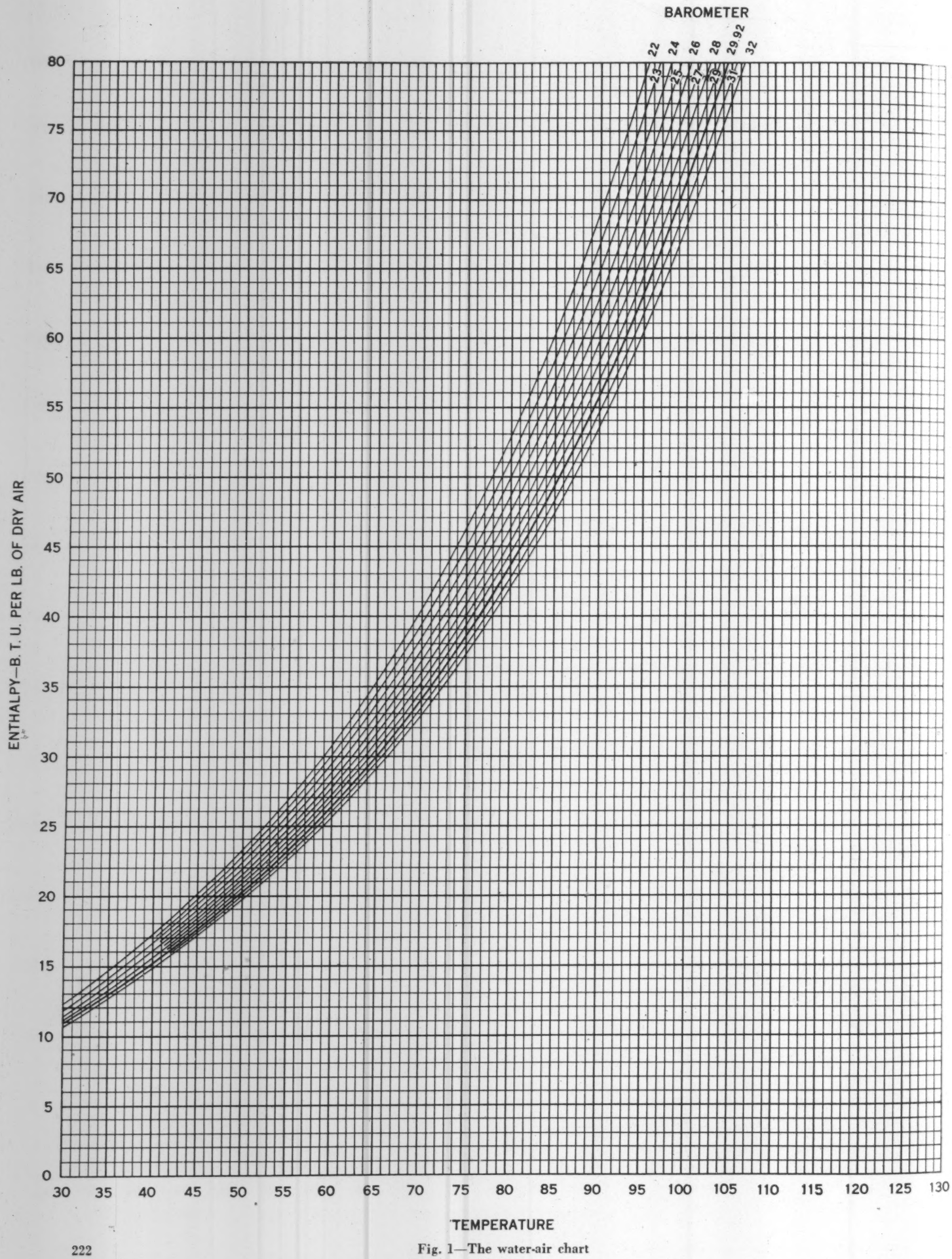


Fig. 1—The water-air chart

perature may be used. As shown in the author's article in HPAC, January, 1938, the error in using this value of enthalpy instead of the true value is ordinarily small.

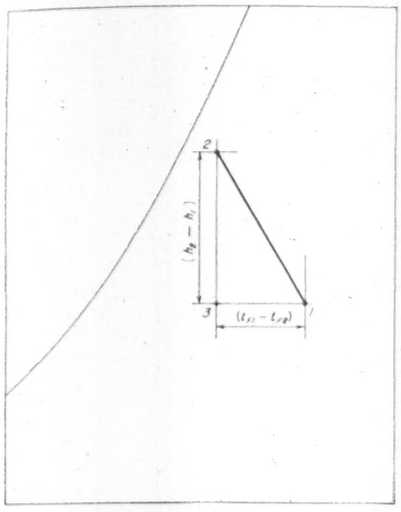


Fig. 2—Straight line *1-2* represents Equation 1

Consequently, if the wet bulb temperature of the air is given, its corresponding enthalpy can be found directly on the water-air chart as illustrated in Fig. 3. First locate on the scale of temperature point *1* representing the wet bulb temperature of the air, t'. Locate point *2*

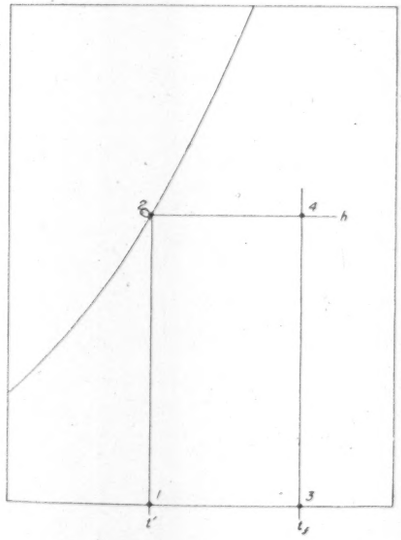


Fig. 3—Diagram illustrating method of locating point representing initial wet bulb temperature of air and initial temperature of liquid

where the vertical line of wet bulb temperature through *1* intersects the saturation curve for the given barometric pressure. The horizontal line through point *2* represents the enthalpy of the air corresponding to the wet bulb temperature, t'. This method of using the approximate enthalpy instead of the true enthalpy will be used throughout this article, although for more accurate results the true enthalpy should be used.

The scale of temperature is also used to represent the temperature of the water. Thus, if the initial wet bulb temperature of the air and the initial temperature of the water are known, the point representing this combination of initial temperatures may be located as illustrated in Fig. 3. The horizontal line representing the initial enthalpy is located as described in the preceding paragraph. The vertical line representing the water temperature can be drawn after first locating the temperature t_f of the water at point *3* on the scale of temperature. Point *4*, representing the desired combination of initial temperatures, is located at the intersection of the vertical line of water temperature through *3* and the horizontal enthalpy line through point *2*.

The curves of barometric pressure shown on the water-air chart simply represent the enthalpy of saturated air at various temperatures for each given barometric pressure. It is obvious that the curve for any given barometric pressure also represents a series of points at which the temperature of the water and the wet bulb temperature of saturated air are exactly the same. At any point to the right of a given barometric curve, the temperature of the water is higher than the wet bulb temperature of the air; to the left, lower.

The water-air chart is applicable to all those problems in which the weight of moisture evaporated into the air or condensed from the air is negligible compared to the weight of water that is being circulated.

In some cases the psychrometric chart (see HPAC, June, 1939, p. 359, and February, 1940, p. 109)

Table 2—Values of N and Θ

N	θ	$(90-\theta)$	N	θ	$(90-\theta)$	N	θ	$(90-\theta)$
0.00	0°— 0′	90°— 0′	0.50	38°—58′	51°— 2′	1.20	62°—45′	27°—15′
.01	0 —56	89 — 4	.51	39 —31	50 —29	1.22	63 — 8	26 —52
.02	1 —51	88 — 9	.52	40 — 4	49 —56	1.24	63 —30	26 —30
.03	2 —47	87 —13	.53	40 —36	49 —24	1.26	63 —52	26 — 8
.04	3 —42	86 —18	.54	41 — 8	48 —52	1.28	64 —13	25 —47
0.05	4°—37′	85°—23′	0.55	41°—40′	48°—20′	1.30	64°—34′	25°—26′
.06	5 —33	84 —27	.56	42 —10	47 —50	1.32	64 —54	25 — 6
.07	6 —28	83 —32	.57	42 —41	47 —19	1.34	65 —14	24 —46
.08	7 —22	82 —38	.58	43 —10	46 —50	1.36	65 —33	24 —27
.09	8 —17	81 —43	.59	43 —40	46 —20	1.38	65 —52	24 — 8
0.10	9°—11′	80°—49′	0.60	44°— 9′	45°—51′	1.40	66°—10′	23°—50′
.11	10 — 5	79 —55	.61	44 —37	45 —23	1.42	66 —28	23 —32
.12	10 —59	79 — 1	.62	45 — 5	44 —55	1.44	66 —46	23 —14
.13	11 —53	78 — 7	.63	45 —32	44 —28	1.46	67 — 3	22 —57
.14	12 —46	77 —14	.64	46 — 0	44 — 0	1.48	67 —20	22 —40
0.15	13°—38′	76°—22′	0.65	46°—26′	43°—34′	1.50	67°—36′	22°—24′
.16	14 —31	75 —29	.66	46 —52	43 — 8	1.55	68 —15	21 —45
.17	15 —23	74 —37	.67	47 —18	42 —42	1.60	68 —52	21 — 8
.18	16 —14	73 —46	.68	47 —44	42 —16	1.65	69 —28	20 —32
.19	17 — 5	72 —55	.69	48 — 8	41 —52	1.70	70 — 1	19 —59
0.20	17°—56′	72°— 4′	0.70	48°—33′	41°—27′	1.75	70°—33′	19°—27′
.21	18 —46	71 —14	.71	48 —57	41 — 3	1.80	71 — 3	18 —57
.22	19 —35	70 —25	.72	49 —21	40 —39	1.85	71 —31	18 —29
.23	20 —24	69 —36	.73	49 —45	40 —15	1.90	71 —59	18 — 1
.24	21 —13	68 —47	.74	50 — 7	39 —53	1.95	72 —25	17 —35
0.25	22°— 1′	67°—59′	0.75	50°—30′	39°—30′	2.00	72°—49′	17°—11′
.26	22 —49	67 —11	.76	50 —52	39 — 8	2.10	73 —36	16 —24
.27	23 —36	66 —24	.77	51 —14	38 —46	2.20	74 —18	15 —42
.28	24 —22	65 —38	.78	51 —36	38 —24	2.30	74 —57	15 — 3
.29	25 — 8	64 —52	.79	51 —57	38 — 3	2.40	75 —33	14 —27
0.30	25°—53′	64°— 7′	0.80	52°—18′	37°—42′	2.50	76°— 7′	13°—53′
.31	26 —38	63 —22	.82	52 —59	37 — 1	2.60	76 —38	13 —22
.32	27 —22	62 —38	.84	53 —39	36 —21	2.70	77 — 6	12 —54
.33	28 — 6	61 —54	.86	54 —17	35 —43	2.80	77 —33	12 —27
.34	28 —49	61 —11	.88	54 —55	35 — 5	2.90	77 —58	12 — 2
0.35	29°—31′	60°—29′	0.90	55°—31′	34°—29′	3.00	78°—21′	11°—39′
.36	30 —13	59 —47	.92	56 — 6	33 —54	3.50	79 —59	10 — 1
.37	30 —54	59 — 6	.94	56 —40	33 —20	4.00	81 —13	8 —47
.38	31 —35	58 —25	.96	57 —13	32 —47	4.50	82 —11	7 —49
.39	32 —15	57 —45	.98	57 —45	32 —15	5.00	82 —57	7 — 3
0.40	32°—54′	57°— 6′	1.00	58°—17′	31°—43′	6.00	84°— 7′	5°—53′
.41	33 —33	56 —27	1.02	58 —47	31 —13	7.00	84 —57	5 — 3
.42	34 —12	55 —48	1.04	59 —16	30 —44	8.00	85 —35	4 —25
.43	34 —49	55 —11	1.06	59 —45	30 —15	9.00	86 — 4	3 —56
.44	35 —26	54 —34	1.08	60 —13	29 —47	10.00	86 —28	3 —32
0.45	36°— 3′	53°—57′	1.10	60°—40′	29°—20′	12.00	87°— 3′	2°—57′
.46	36 —39	53 —21	1.12	61 — 6	28 —54	14.00	87 —28	2 —32
.47	37 —15	52 —45	1.14	61 —32	28 —28	16.00	87 —47	2 —13
.48	37 —50	52 —10	1.16	61 —57	28 — 3	18.00	88 — 2	1 —58
.49	38 —24	51 —36	1.18	62 —21	27 —39	Inf.	90 — 0	0 — 0

can be used as well as the water-air chart. However, practically the psychrometric chart is not so well suited for this type of work because: (a) on the psychrometric chart the vertical lines of dry bulb, which would be used for the water temperature, do not extend past the saturation curve, and (b) it is not always possible to obtain a point of intersection between commonly used wet bulb and water temperatures. For example, on the psychrometric chart, the line of 75 deg wet bulb temperature does not intersect the extension of the 45 deg dry bulb line, which would be used for an initial water temperature of 45 deg.

N-Lines

The method of drawing the straight line representing Equation 1 is illustrated in Fig. 4, which represents the heating of air by water in parallel flow. For this case point

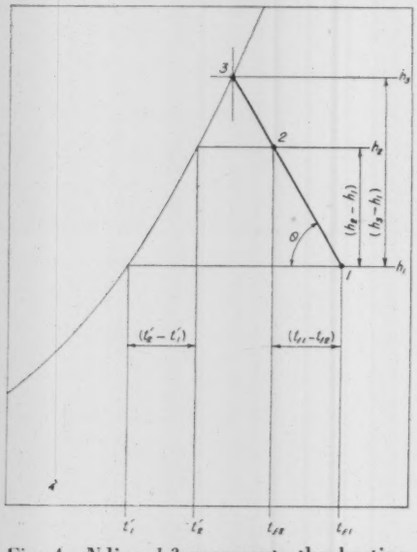


Fig. 4—*N*-line *1-3* represents the heating of air by warm water. Angle θ is measured from the horizontal

1, representing the intersection of the initial temperature of the water and the initial enthalpy of the air, is located as described in the preceding section. Straight line *1-2* is then drawn through point *1* at an angle θ with the horizontal. The value of the angle θ depends upon the value of N and may be found in Table 2. (The relationship between N and θ is derived in the section below entitled Relation Between N and θ.) A line such as *1-2* whose slope depends upon the value of N will, for convenience, be called an *N-line*.

The N-line shows the relationship between the temperature of the water and the wet bulb temperature of the air at any time. At any point on an N-line, the wet bulb temperature of the air corresponding to any given water temperature can be determined. For example, if at any time the water is cooled to a final temperature represented by the vertical line through point *2* of Fig. 4, the final wet bulb temperature of the air at that same time is read where the horizontal enthalpy line through *2* intersects the saturation curve for the given barometric pressure.

Exchange of Heat Between Air and Liquid

The exchange of heat between air and a liquid which is used to cool or heat the air is represented by the following simple equation.

$$G' c' (t_{f1} - t_{f2}) = h_2 - h_1 \quad \ldots\ldots [2]$$

This equation may also be written

$$G' c' = \frac{h_2 - h_1}{t_{f1} - t_{f2}} \quad \ldots\ldots\ldots\ldots [3]$$

It is apparent that the left-hand members of Equations 1 and 3 are equal. Consequently, for an exchange of heat between air and water,

$$N = G' c' \quad \ldots\ldots\ldots\ldots\ldots [4]$$

Obviously Equations 2 and 4 are applicable regardless of whether the air and water are in direct contact with each other or whether they are separated by a metallic surface, as in a cooling coil. This equation is also true whether the moisture content of the air changes or whether the moisture content remains constant.

When air and water are in direct contact with each other as in a spray chamber, the moisture content of the air must change. However, when the air and water are separated by a metallic surface as in a cooling coil, it is possible for a change in the enthalpy of the air to take place without any change in the moisture content occurring. But if the temperature of the water inside the coil is sufficiently lower than the dew point temperature of the air, the moisture content of the air will change and the surface of the coil will be covered with a film of moisture condensed from the air. In this case the air will be in direct contact with moisture exactly as in a spray chamber.

Fig. 5 shows the temperature of the water and the enthalpy of the air for the case illustrated in Fig. 4.

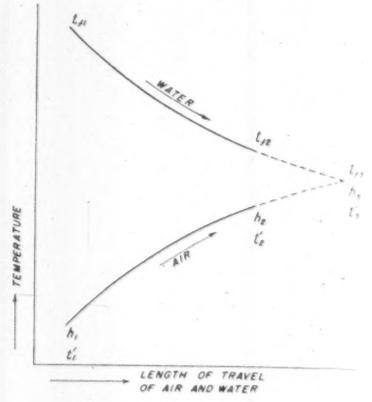


Fig. 5—Heating air with warm water in parallel flow

As is apparent from Fig. 5, the longer the water and air are in contact with each other, the closer the final temperature of the water and the final wet bulb temperature of the air will approach each other. If the heat transfer process were perfect, the final wet bulb temperature of the air would theoretically be equal to the final temperature of the water.

This theoretical final temperature to which water can be cooled and air heated may be found as in Fig. 4 at point *3* where line *1-2* intersects the saturation curve for the given barometric pressure. The temperature read at point *3* is theoretically the highest temperature to which the air can be heated and the lowest temperature to which the water can be cooled in parallel flow for the conditions represented by N-line *1-2* of Fig. 4. Of course, in an actual spray chamber the final temperatures of the air and water would be represented by a point such as *2*. The actual location of point *2* on line *1-3* depends upon such characteristics of the apparatus as the length of time that the air and water are in contact with each other, fineness of the water spray, air velocity, and so forth.

It is possible to express the efficiency of the apparatus in terms of the theoretical amount of heat that could be transferred in a perfect apparatus. Thus, for a perfect apparatus, the final condition of the air would be represented by point *3* of Fig. 4 and the amount of heat that could be transferred would be

$(h_3 - h_1)$. However, in an actual apparatus if the final condition of the air were represented by, say, point 2, the amount of heat actually transferred would be $(h_2 - h_1)$. The ratio of the actual quantity of heat to the theoretical quantity of heat transferred may be defined as the efficiency of the apparatus, or

$$E = \frac{h_2 - h_1}{h_3 - h_1} \quad \ldots\ldots\ldots\ldots\ldots [5]$$

Knowing the efficiency of a given apparatus, point 2 can readily be located because the ratio of length 2-1 to length 3-1 equals the efficiency.

Relation Between N and θ

Referring to Fig. 2,

$$\tan\theta = \frac{2-3}{1-3} \quad \ldots\ldots\ldots\ldots\ldots [6]$$

But

$$2-3 = \frac{h_2 - h_1}{s_h} \quad \ldots\ldots\ldots\ldots\ldots [7]$$

and

$$1-3 = \frac{t_{t1} - t_{t2}}{s_t} \quad \ldots\ldots\ldots\ldots\ldots [8]$$

Substituting (7) and (8) into (6),

$$\tan\theta = \frac{s_t}{s_h}\,\frac{h_2 - h_1}{t_{t1} - t_{t2}} \quad \ldots\ldots\ldots\ldots\ldots [9]$$

But Equation 1 is,

$$N = \frac{h_2 - h_1}{t_{t1} - t_{t2}} \quad \ldots\ldots\ldots\ldots\ldots [10]$$

Substituting (10) into (9),

$$\tan\theta = \frac{s_t}{s_h} N \quad \ldots\ldots\ldots\ldots\ldots [11]$$

For Fig. 1, $s_t/s_h = 1.6176$.

[This is the first of a series of articles on the water-air chart.]

» » »

Air conditioning installations sold during the month of February in Chicago totaled 30 in number, 21 of which were central plants, according to the Commonwealth Edison Co. These 30 installations represented 5170.25 tons and 5398 hp.

Biggest of the jobs was an industrial installation of 3750 tons and 3750 hp for the new Studebaker aircraft engine plant being erected at Archer and Cicero. There was also a big commercial job listed, a 1000 ton, 1150 hp installation for basement areas in Marshall Field & Co.'s store. Five of the installations were for general offices.

Sixty air conditioning installations accounting for 1090.37 hp were contracted for during January and February, in New York (Manhattan, Bronx, Brooklyn, Queens), the Consolidated Edison Co. reports.

Why a Pounding Noise in Hot Water Supply System?

F. M. Dawson, Director, Iowa Institute of Hydraulic Research, Gives Probable Reasons in Answering Question from a Reader

WE ARE having trouble with a 30 gal vertical range boiler making a pounding noise when the water is being heated," writes a bone products manufacturer. "We are wondering if you can advise us what causes this trouble and how it can be corrected."

* * *

In answering this question, it is assumed in analyzing the probable causes of pounding noise in the hot water supply system, that such pounding is not a water hammer phenomenon — since water hammer pounding would occur whenever valves were being operated, no matter whether the water was being heated or not. Of course, water hammer is quite common in hot water lines because of the high velocities due to the tendency to use small pipes and spring operated faucets. The cure for water hammer noises is the installation of air chambers or other relief devices on the pipes near the quick closing valves.

Noises other than those due to water hammer may occur during the time the heater is operated for a variety of reasons. Probably one of the principal causes of such noises is the overheating of the water in contact with the heating surface because of poor circulation between the heater and the storage tank. If the heater is separate from the storage tank, the heated water circulates through the heater and goes up to the top of the storage tank. However, if for some reason this circulation is too slow, the water in immediate contact with the heating surface may turn into steam. The collapsing of these steam bubbles will set up a very disagreeable crackling noise and vibration.

Poor circulation may be due to the fact that the pipes or coils are full of lime and too small for maintaining adequate circulation. Also, the heater may be so situated with respect to the storage tank that the circulating head is too small. The heater should be as far below the top of the tank as convenient. If the heating coils are lined thickly with lime or other deposit, water may get into the cracks of such deposits and become overheated, producing steam bubbles which when they rise and come into contact with the colder water, collapse and produce a sharp noise. This phenomenon is noted in tea kettles which are heavily coated with lime.

If the heating source is separate from the storage tank, it is important that the piping connections between it and the tank are such so there is no opportunity for air to collect and hinder the circulation. Ordinarily, if it can be avoided, the hot water coming from the heater and going to the tank should rise continually; it should not be made to flow down. If it is made to flow down into the top of the tank, the pipe connection to the fixtures should be taken off from the highest point of the piping between the heater and the tank, thus preventing the accumulation of air pockets.

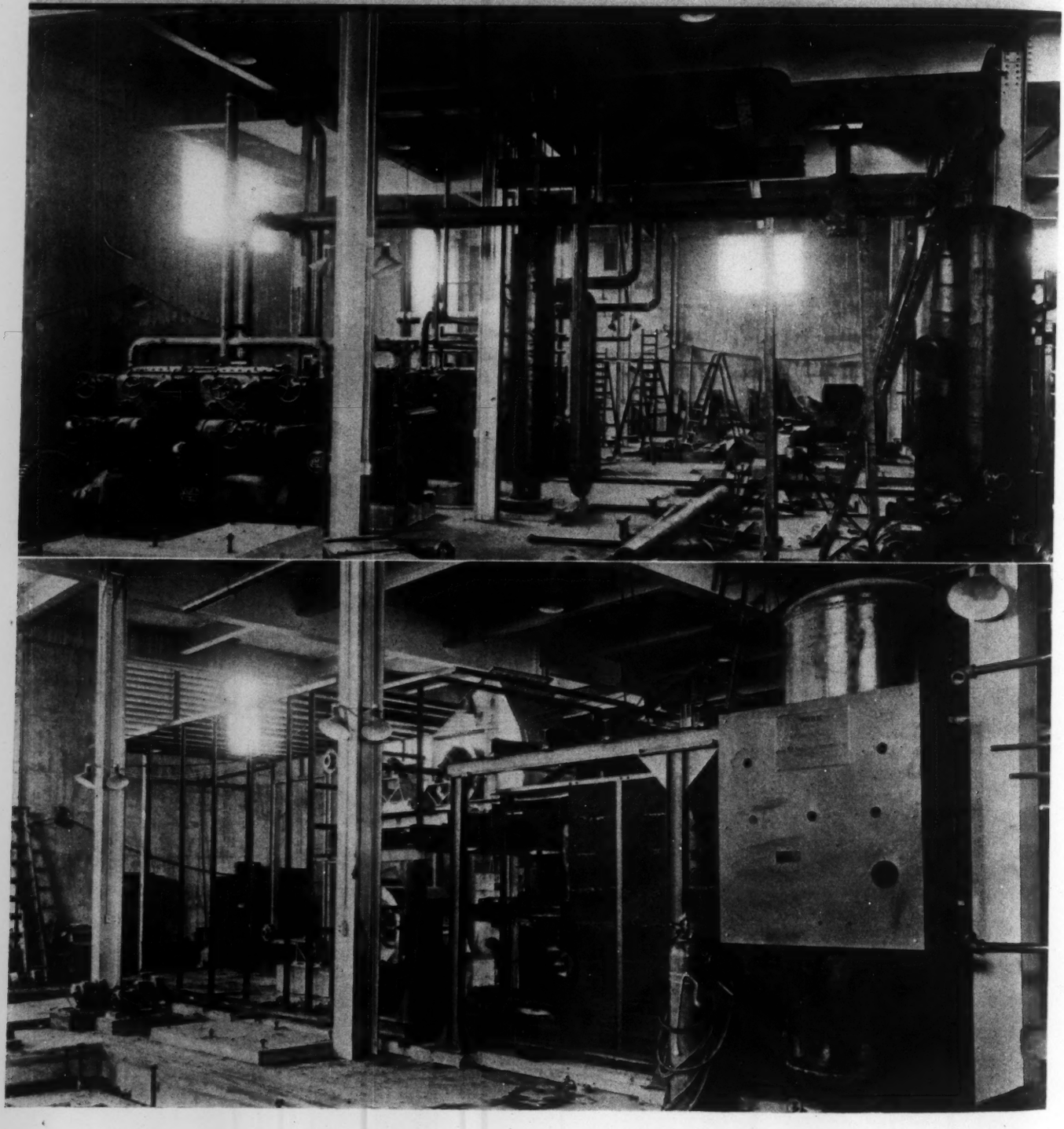
Perhaps there is some other obscure reason for the pounding noise when water is heated; however, the chances are that the fundamental cause will be similar to that mentioned.

» » »

And then there's the clerk who returned the piping specifications to the consulting engineer with the demand that the words "or equal" be inserted each time the valve designation "O S & Y" appeared. . . . He's probably a cousin of the fellow who turned down a proposal for a fan with an outlet velocity of 1700 fpm because the spec read the fan should have a maximum outlet velocity of 1800 fpm; 1700 wasn't close enough, he said.

Construction for Defense

Testing Army Aircraft Engines



WHO has not marveled—as an airplane circles high overhead—at the engineering genius of man which permits him to explore the uppermost regions of our old Earth's atmosphere —up where the sky is not blue but black—where the air is so thin that ordinary propellers won't pull in it —where air pressure and temperature are so low that special, airtight, insulated cabins are necessary to preserve human life? In recent years hardy scientists have studied the extreme upper air (usually referred to as "stratosphere") at great personal risk and discomfort.

In testing new stratospheric devices much time, expense and danger is avoided in applying the knowledge which has been gained by stratospheric observation to produce similar conditions on the ground. One of the most outstanding stratospheric testing laboratories in the country is that now being completed by the Army Air Corps at Wright Field, Dayton, Ohio. Here is the largest air cooling plant of its type in existence, designed to provide air testing temperatures down to 67 F below zero.

Nine years ago a battery of carbon dioxide compressors and cooling coils were installed at Wright Field to produce test room temperatures down to —40 F and carburetor air temperature of as low as —50 F. The new testing plant will produce even more severe conditions, equivalent to the higher altitudes at which aircraft engines are expected to operate today.

At 35,000 ft above sea level, air temperature is 67 F below zero and atmospheric pressure is about 4 lb per sq in., as compared to the 14.7 lb to which we are accustomed. These are the extreme conditions which army engineers may want to attain in testing their aircraft engines in the new engine testing laboratory.

. . . The upper picture on the opposite page is a construction view of the refrigerating room, showing in the left foreground the booster compressors for the third stage of air cooling and behind them the second and first stage compressors. The intercooler apparatus is in the center. The lower picture—also a construction view—shows on the left the framework for the first and second air cooling stages. On the right is the low pressure ammonia receiver for the third stage and behind it may be observed one end of the third stage wind tunnel

Stratospheric low pressure conditions can be simulated by throttling the carburetor supply air to the engine, and exhausting the engine into a vacuum. The carburetor supply air is cooled down to a minimum of —67 F and the gasoline supply to 0 F. The evaporators which reduce the gasoline temperature to 0 F are three horizontal shell and tube coolers, each capable of handling the full

By T. H. Eakle, Jr.*

load alone, hooked up to an 8 in. x 8 in. ammonia compressor.

The cooling system for the carburetor supply air offered a real challenge to the engineers. Army requirements called for an installation of great flexibility of operation, designed for widely varying loads.

Briefly, the system must be able to cool huge quantities of air to a minimum temperature of —67 F, operating with any inlet air temperature from maximum down to —10 F. Further, air quantities cooled may vary over a wide range. It was decided to handle this difficult job in three separately controlled cooling stages.

A separate set of ammonia compressors operates on each of three separate evaporators, with all of the compressors discharging into a common condensing system.

First Stage—The first step is to cool the air from 100 F to 35 F. This is done in a spiral finned coil evaporator, containing water sprays, connected to an 11½ in. x 10 in. ammonia machine operating at 45 lb suction pressure.

Second Stage—In the second stage the air is cooled from 35 F to —13 F. The evaporator is identical to that of the first stage except that a solution of ethylene glycol is sprayed over the coils, instead of water. The ethylene glycol prevents frost accumulation to maintain high evaporator efficiency. This moisture picked up by the ethylene glycol, which would otherwise turn to frost, is boiled off in a "concentrator" before re-spraying. One 10 in. x 10 in. ammonia four cylinder compressor and one 11½ in. x 10 in. four cylinder ammonia compressor supply refrigeration at 3 lb suction pressure.

Third Stage—To cool the air to —67 F after leaving the second stage, eight nests of trombone coils are arranged in an air tunnel to provide progressive cooling at —77 F evaporator temperature. One 10 in. x 7½ in. two cylinder and two 15 in. x 10 in. four cylinder ammonia booster compressors draw the ammonia vapor from the trombone coils and discharge it at higher pressure through intercooling equipment into the second stage suction lines.

The entire casing surrounding the three air stages is airtight and thoroughly insulated with cork. A fan situated between the second and third stages pulls air through the first two stages and pushes it through the third, so that air is delivered at the end of the third stage at —67 F and atmospheric pressure. At this point, secondary fans pick up the air and distribute it through heavily insulated duct work to the separate airplane engine testing rooms, one or all of which may be in use at any given time.

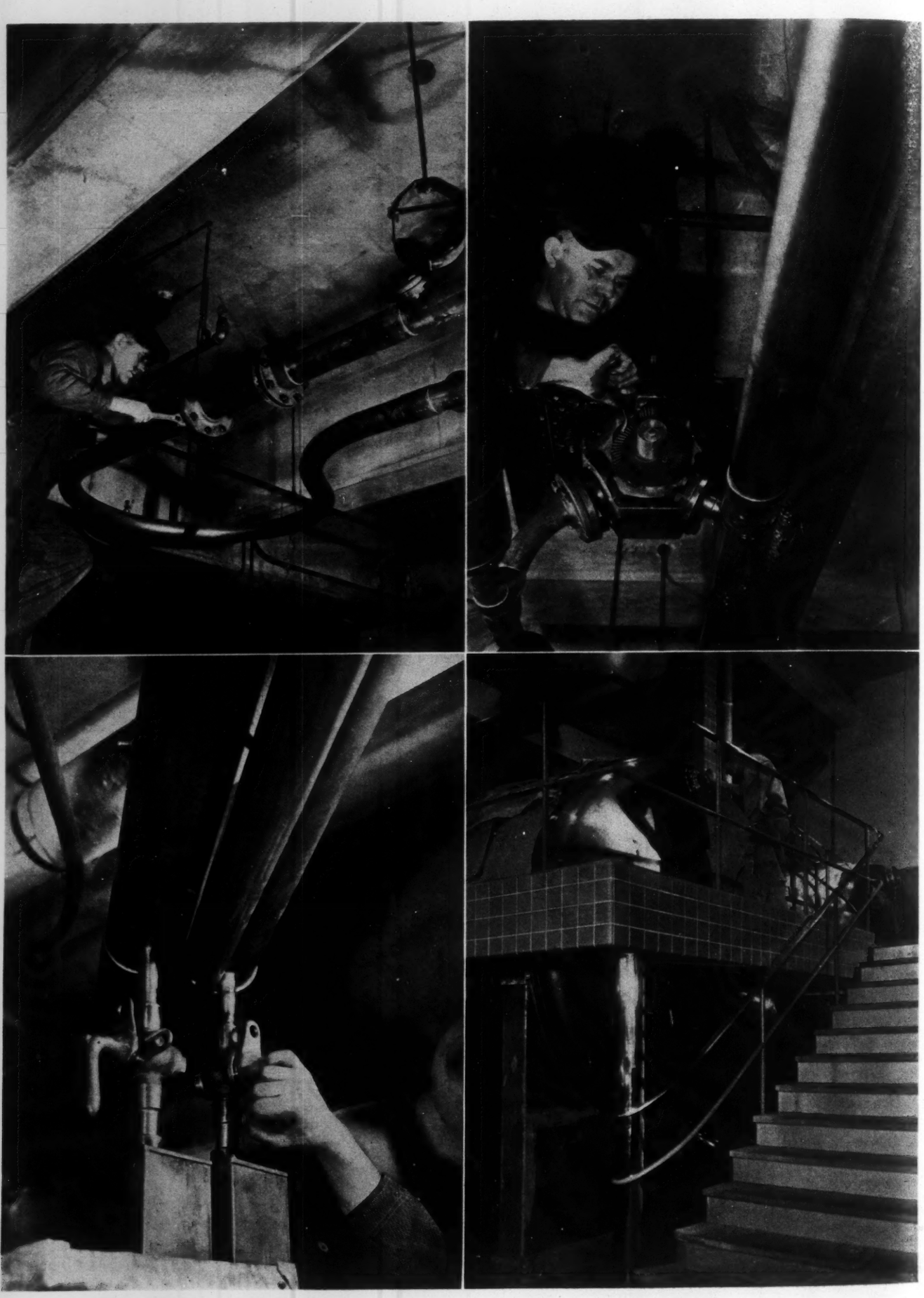
The third wind tunnel is divided into two sections so that hot gas may be used to defrost one-half of the tunnel while the other is still operating. No defrosting is necessary in the first and second stages.

The common condensing system consists of two horizontal shell and tube condensers, into which all the ammonia compressors discharge (the boosters indirectly through the second stage compressors). After condensing, the liquid ammonia goes directly to each of the three evaporators, passing through an intercooler in Stage No. 3.

The extremely low temperatures to which the air is reduced before going into the engine testing rooms precipitate most of the moisture from the air, thus simulating the dry air conditions which exist at high altitudes. However, it may be desirable to raise the temperature of this extremely dry air after moisture precipitation, and for this purpose individually controlled reheaters are situated at the air inlet in each of the four engine testing rooms.

The reheaters are standard copper finned coils, heated by a solution of ethylene glycol.

*Assistant manager, industrial refrigeration division, York Ice Machinery Corp.



PIPING FOR PACKAGING

Brewery Bottling Department Has Output of Over 21 Units per Second; Beer Is Conveyed in Nickel Tubing

EFFICIENT operation and the most modern equipment make it possible to fill, cap and pasteurize a combined total of 1280 bottles and cans a minute in the new bottling department of the F & M Schaefer Brewing Co., Brooklyn, N. Y. This represents an average output of more than 21 units a second!

Complete with a modern conveyor system and electric eye counters, the bottling building occupies the equivalent of a full city block. Production was started at this plant last October with four machines for bottling pints, two for quarts, and two units for canning beer. These machines have a total packaging capacity of 314 barrels per hour.

From storage cellars to the adjoining brewery, the beer is carried to the bottling machines through 680 ft of 4⅛ in. nickel tubing. This tubing is refrigerated and tests have shown that beer can be left lying in it for several days yet retain the exact temperature, carbonic gas content, quality and taste it had when leaving the glass lined storage tanks. Thus the use of nickel piping does away with the need for emptying the pipe line each night, a necessary procedure formerly. The economies are twofold: There is a saving of the beer wastage and labor involved in cleaning, and the troubles caused by air getting into the pipe line during cleaning and the difficulties of trying to remove it are no longer a daily problem. Air in the line foams the beer and prevents its uniform flow into the bottling machines. Yet it is extremely difficult to prevent air from remaining after cleaning, and equally difficult to get it out. It had taken on occasions as much as a whole day, for example, to remove air so the bottling machines could operate properly.

Despite the protection nickel affords, the brewer's ancient custom demands that the pipe line be cleaned occasionally. A saline solution, water and rubber sponges are used for this purpose. Nickel alloy valves situated at the lowest point in the line are opened as a drain when cleaning has been completed.

Once in the bottling department, beer is piped upstairs to the filling room through nickel alloy regulating valves. Here the containers are filled, capped, labeled and pasteurized as they travel along on conveyors. Whole cases can be filled automatically at one time.

The present modernization program was started in 1933 with the erection of a new power plant, stock house, and office building. New equipment installed includes mash tubs and cereal cookers with nickel heads covering the insulation and two monel vormashers.

Above and top left on opposite page—**To preserve the flavor, color and purity of its beer, the F & M Schaefer Brewing Co. uses a refrigerated pipe line of pure nickel 680 ft long to carry the beverage from storage cellars to a bottling department. Nickel keeps the beer in excellent condition overnight, thus eliminating the need for emptying the pipe line at the close of each day. Note the 90 deg bend on a 24 in. radius made without wrinkling the inside or noticeably stretching the outside radius. The sleeve joints were soft soldered. Schock-Gusmer Co. fabricated and installed the piping. . . . *Top right*—Installing a three way nickel alloy regulating valve through which beer that has been piped from the storage cellars will be fed to the bottling department on the floor above. Designed by Schaefer's engineers, the valve is reinforced with a hexagonal member to prevent leakage should the valve body become distorted by strains from the pipe line. . . . *Bottom left*—Opening a nickel alloy valve at the low point in the pipe line to drain off the saline solution after a periodic cleaning. The metal boxes shown are sealed by the government so containers cannot be filled with beer at this point. . . . *Bottom right*—One of the two mash tubs in Schaefer's brew house. The heads covering the insulation are of solid nickel because of the ease of fabrication**

"Open for Discussion"

Communications to the Editor

Like a Spring Day —Air Conditioned

THE EDITOR:

The article in the March HPAC by H. L. Schwenker covering the air conditioning in the Lincoln Liberty Life Insurance Co.'s building at Lincoln, Neb., is very interesting.

Some of the most interesting comments made on this installation come from people from outside who are not tenants of the building but who, in the course of the day, call on their clients in this building as well as many other air conditioned buildings in Lincoln. Their comments as repeated to me were a comparison between the "feel" of the air, or atmosphere, in the Lincoln Liberty building with that of other air conditioned buildings. The comments are usually to the effect that the atmosphere is like that of a spring day, when the air feels fresh and moist.

A number of facts no doubt contribute to the successful operation of this system—one being the fact that an ample amount of outside air is brought into the building. This air is drawn in through a fully automatic air filter, then through a precooling coil by a fan which discharges it down to the air conditioning units on various floors.

The city water of Lincoln is very cold—about 60 F—and this water is used in the precooling coil in the attic, and the sensible heat of the incoming air is reduced from 20 to 30 F. At the same time this air is dehumidified to a great extent. The precooling water, after passing through the above mentioned coil, is returned to the condensers in the basement at a temperaure of about 70, and after passing through the condensers is discharged to the sewer at a temperature of between 90 and 100.

Only about two-thirds of the air supplied to the various floors is recirculated, the balance being taken down through ducts to the main vestibule where it is discharged through an exhaust fan into the vestibule and is thus utilized for cooling the vestibule as well as some rooms on the first floor.

We feel very proud of the satisfactory operation of this installation, and believe that it is due to a great extent to the interest which Mr. Schwenker has taken; he has gone to the trouble of seeing that the equipment has proper care and attention and has been operated in the manner in which it was intended to be operated.—WALTER E. GILLHAM, Consulting Engineer.

Air Change —Once a Major Criterion

THE EDITOR:

Mr. Ashley's article, Air Change —Once a Major Criterion, in the March HPAC is very much to the point and we should do just as his first paragraph recommends and abandon the use of "air change." In the doing, however, we must consider the necessity for other yardsticks and means of measurements by which we can set up criteria for air distribution and ventilation for satisfactory performance in the occupied spaces.

Proper distribution is all-important if desired results are to be obtained, but existing methods and means for measuring and expressing distribution in a conditioned space are certainly lacking in ease of use and definitive quality for expressing what is accomplished.

In discussing air distribution, we all fall back on such expressions as "drafts," "velocity in the occupied zone" and the like. But these expressions have various meanings with various people and practical instruments are lacking for making determinations that will truly measure. Often, what is called a draft in a conditioned space would be called a pleasant breeze outdoors.

The technical committee on air distribution and air friction of the research committee of the ASHVE now has a program of research underway that will supply some of the answers to the distribution problem. This work already has shown the necessity of new instruments, new units of measurement and new methods of expression in order to make results intelligible and useful to others than the experimenters themselves.

These new things are definitely needed as a means to evaluate the operation of conditioning systems, to set up in specifications required results from the systems and to permit codes to define proper conditions.—S. H. DOWNS, Chief Engineer, Clarage Fan Co.

Readers of HEATING, PIPING AND AIR CONDITIONING are invited to contribute their views to this "Open for Discussion" page, which will appear from time to time. Comments on articles we have published, expressions of timely interest on developments in design, installation, operation or maintenance of heating, piping or air conditioning systems, other remarks of value to HPAC's readers—all will be welcomed by THE EDITOR.

Black Hole of Calcutta

THE EDITOR:

Apropos the article in HPAC for March on the subject of Air Change—Once a Major Criterion, our Kansas City office points out that, amusingly enough, Mr. Ashley's article is followed by a reference to the Black Hole of Calcutta and the statement is made that "next morning 123 were dead for lack of ventilation, excessive heat and humidity."

Our Kansas City office suggests that you might very well have said "air change" because it is fairly certain that that was what they died "for lack of." Certainly air change was a "major criterion" in that situation in 1756 and it is not clear to us how any of the physical laws that were in existence at that time have been changed.—J. M. FRANK, Ilg Electric Ventilating Co.

RADIANT HEATING
—With Cast Iron Panels

F. W. Hutchinson, of the University of California, Describes and Discusses a Method Used in Europe

THE principle of heating or cooling by means of low temperature radiant energy consists essentially in establishing a designed fraction of the total internal surface of the room at a temperature determinable from the heat transfer characteristics of the structure and the comfort requirements of the occupants. The effectiveness of such a system is then a function only of the area and temperature of the panel surface, which acts in winter as a heat source and in summer as a heat sink. Obviously, therefore, selection of a particular type of panel is not dictated by radiant comfort theory, but follows from considerations such as relative responsiveness to control, flexibility of operation, and ability of the panel to provide the requisite energy transfer from the circulating fluid to the working surface. Other factors influencing the selection are maintenance and repair experience, structural requirements, architectural desirability and first cost.

The intent here is to describe and discuss a widely used European method of panel construction which has received but scant attention in the United States. This method, using cast iron plates, differs strikingly from the sinuous embedded coil and electric fabric systems of which adequate descriptions have already appeared. Basic differences are:

1) The cast iron panel is manufactured complete in standard sections ready for assembly and installation by the heating contractor.

2) The panel surface receives heat transferred from cast iron waterways and is itself either an integral part of the waterway casting or a steel plate affixed to that casting.

3) Units are attached to or recessed into the ceiling or wall, but do not become an integral part of the structure. For this reason they are sometimes referred to as "applied" in contrast to "embedded" panels. Architecturally the unit is therefore at a disadvantage when compared with the sinuous coil or electric fabric methods since it is not invisible.

If a cast iron panel system were operated at the surface temperature used with embedded panels the comfort characteristics, energy require-

SUMMARY—A method of panel construction for radiant heating used widely in Europe but which has received scant attention in the United States is described and discussed by Mr. Hutchinson, instructor in the department of mechanical engineering at the University of California. He writes from a first hand knowledge, for he has spent two summers abroad making studies of radiant heating and cooling. . . . The method utilizes cast iron plates manufactured in standard sections ready for assembly and installation by the heating contractor. The units are attached to the ceiling or wall but do not become an integral part of the structure; for this reason they are sometimes referred to as "applied" rather than "embedded" panels. . . . The various types of these panels are described and analyzed. The author concludes by pointing out that such panels are not intended to be competitive with low temperature (90-100 F) ceiling panels, but when used in the temperature range for which they have been developed, they provide a means of realizing some of the characteristics of radiant heating

Fig. 1—Installation of all cast iron panels comprising a casting flat on one side and with integral water passages on the other

ments and equilibrium performance of the two systems would be similar. In practice, the panel manufacturer recommends its use at temperatures higher than those common with sinuous coils; in consequence, a direct comparison of performance is not possible. Differences occur in a number of respects.

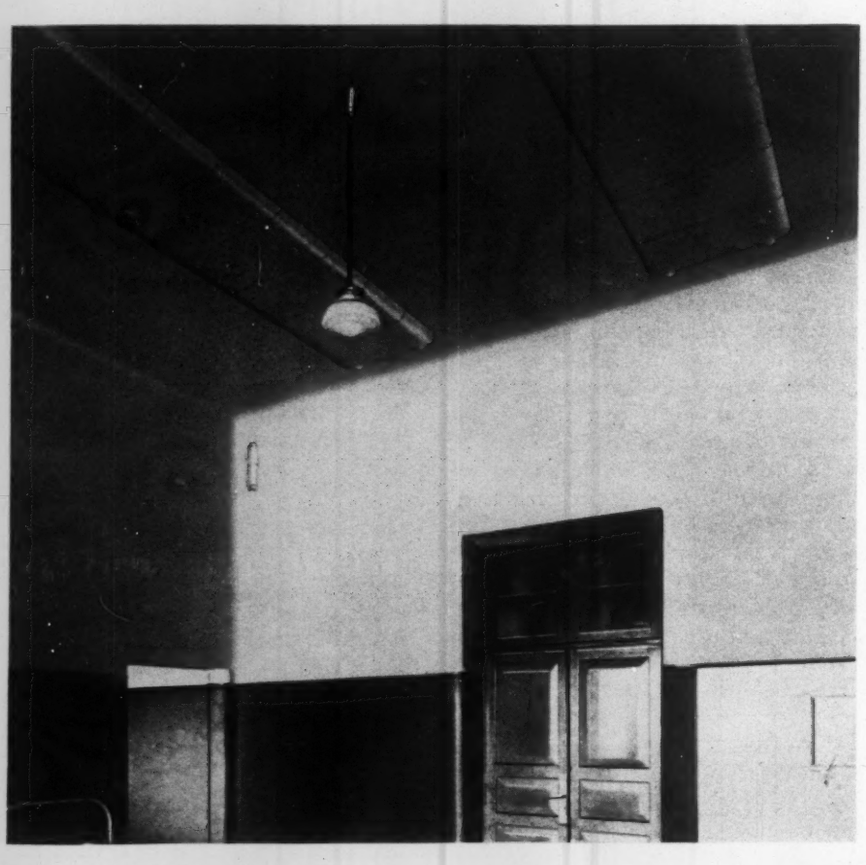


Fig. 2—Another view of hospital shown in Fig. 1. The panels are on the ceiling

High Temperature

Hot water above 160 F or steam is customarily used as the heating medium. The higher surface temperature consequently increases the panel rating and reduces by approximately one-half the necessary panel area. While such a reduction is desirable in terms of first cost it tends to obviate one of the principal advantages claimed for panel warming: uniformity of heating effect. In this respect the need for a careful analysis of panel position in terms of its shape factor with respect to the occupants is of greater importance with this type than with low temperature (90-100 F) panels. The manufacturer takes this into account by recommending arbitrary reductions in rated heating effect for installations which differ from a stated design standard.

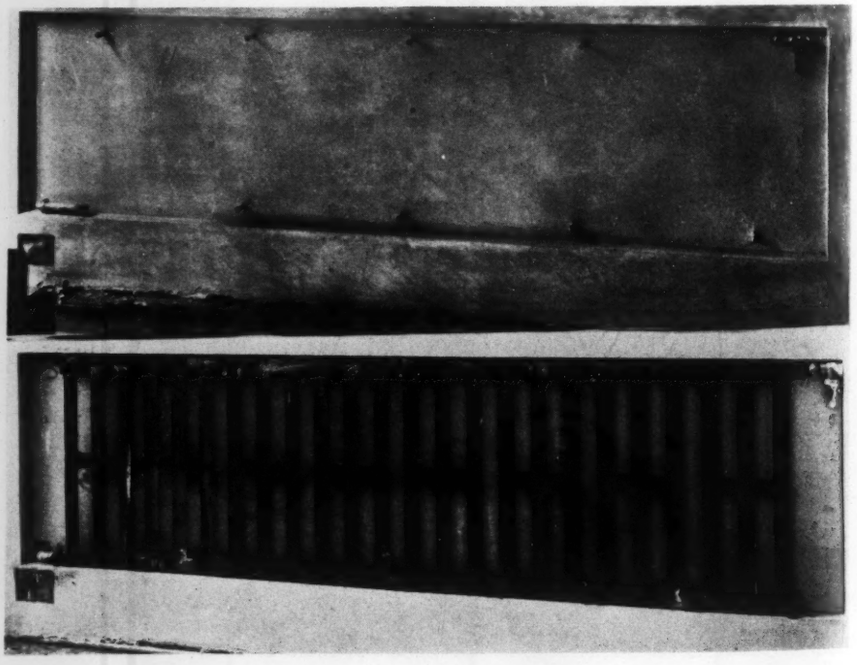


Fig. 3a (above)—Wall recess prepared for installation of panel comprising independent cast iron waterway section to which is attached a flat steel sheet. . . . Fig. 3b (below)—Waterway in position and ready for the plate. Insulation board has been placed behind the waterway

Another result of the higher flow temperature is a more rapid cooling rate and consequently an improved response to changes in the outside temperature. Responsiveness is further assisted by the lower thermal capacity of these panels—a characteristic which is also of value in that it reduces the requisite heating up period. This latter effect, however, is not a serious disadvantage of other types of panels since such systems are intended for continuous operation during the heating season.

Capacity

The cast iron panels are regularly used for floor and wall as well as for ceiling installations. Calculations based on the published ratings show that the percentage of the total heat dissipation which occurs by radiation is 53, 56 and 75 per cent for floor, wall and ceiling respectively. On this basis the convective heat transfer increases by

$$\left[\left(\frac{100-53}{53}\right) \div \left(\frac{100-75}{75}\right)\right] 100 = 265 \text{ per cent}$$

when a panel is moved from the ceiling to the floor; it follows that floor installations (and wall also, though to a lesser degree) represent a compromise between radiant and convective heating and the characteristics of such systems must be somewhere between those of low temperature radiant ceiling panels and of warm air heating installations. Such advantages as accrue

from radiant heating are therefore realized to a lesser extent as the panels are moved down from the ceiling. (Note that for radiant cooling the opposite is true.)

Method of Sizing

Determination of the necessary panel area for a given installation is based on heat losses calculated exactly as for a convective system, but used with equivalent panel ratings which are an index of the relative heating effect. For floor, wall and ceiling panels the heating effects are said to be 25, 33 and 50 per cent, respectively, greater than the actual heat dissipation rates. Thus the requisite area of ceiling panel would be determined by dividing the standard room heat loss by 1½ times the actual rating of the panel. *On this basis* the fuel requirements of a cast iron panel heated structure would be less than for convective heating by 20, 25 or 33 per cent, depending upon whether the panels were situated in floor, wall or ceiling.

Construction

These cast iron panels are factory made in standard sections of four types. The requisite heating surface for a given installation is obtained by connecting in series, by means of right-left internal nipples, the necessary number of sections.

One type is a 100 per cent cast iron unit made in sections 16 in. wide by 18, 24 or 30 in. high. The casting is flat on one side with integral water passages on the other. Heat flows from the fluid passages through the plate by conduction; spacing of the waterways is designed to effect a relatively uniform temperature across the front surface. A flanged bead is cast at the back of the plate and the unit is adapted for flush, recessed or projected fixing. This type has an actual heat dissipation rate of 170 Btu per sq ft per hr when installed in the ceiling, operated with a water to air temperature difference of 100 F and insulated with 2 in. of rock wool. Figs. 1 and 2 show typical installations in an Italian hospital.

Another type differs radically from the foregoing. It consists of an independent cast iron waterway section to which is attached a flat 14 ga sheet steel plate. The unit is lighter and less costly than the all cast panel and is somewhat more adaptable since it is possible to affix a plate of any desired shape and size. It is designed for flush installation in either wall or ceiling.

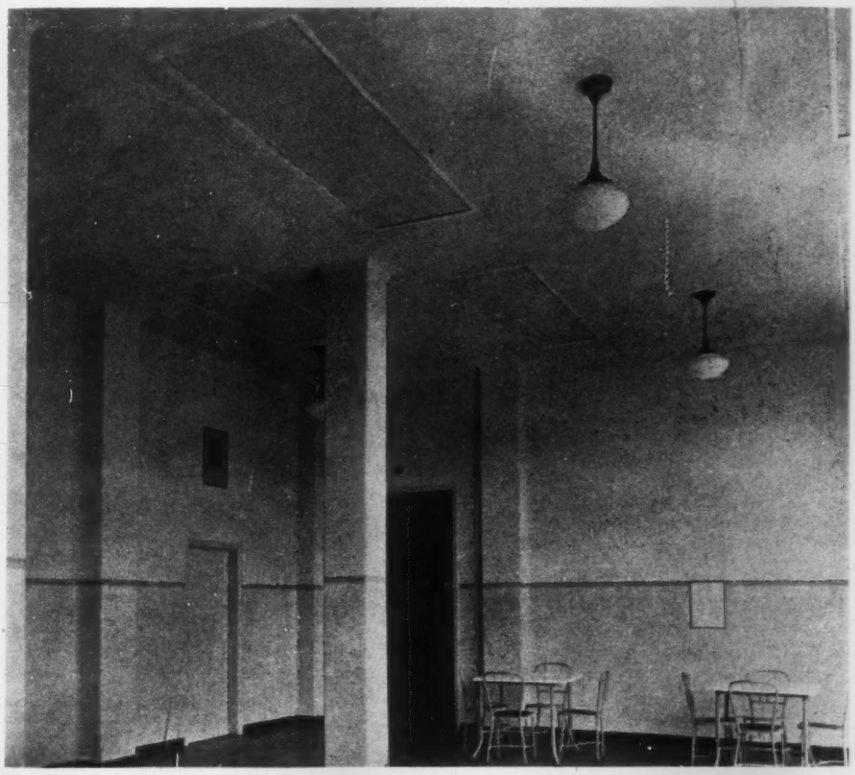


Fig. 5—A completed ceiling installation. The molding around each hot plate insures an air tight connection to prevent streaking the unheated ceiling with dust

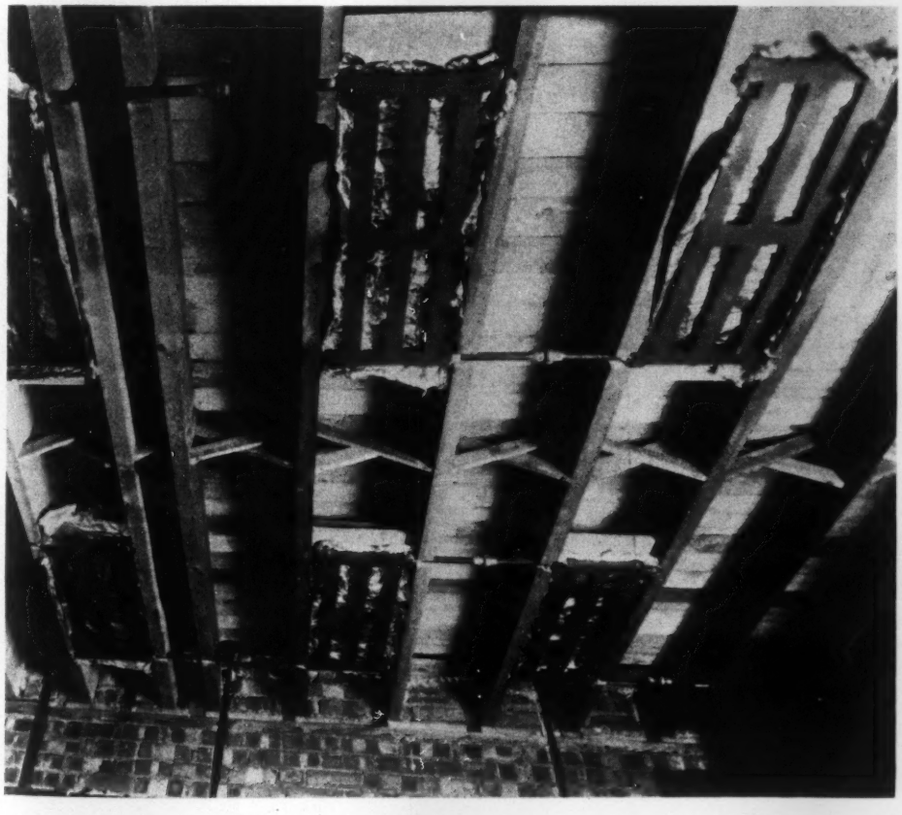


Fig. 4—Same type of panels as shown in Fig. 3 used in a ceiling and foil insulated

Fig. 3a shows a wall recess prepared for this type. Studs are embedded in the wall at regular intervals and on these the cast waterways will be hung. Hot water or steam will enter through the valve shown in the upper right hand corner of the recess and after passing diagonally through the heating elements will exit through the discharge pipe shown in the lower left.

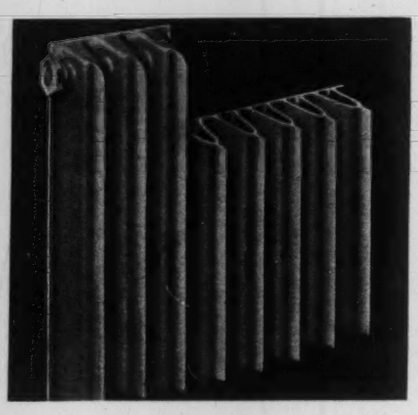


Fig. 6—This type of panel has an extended surface on the back over which air passes to be heated by convection. This unit really resembles a convector more than it resembles a radiant panel

Fig. 3b shows the waterway in place. Note that the heating unit consists of eight sections connected by internal nipples. In this figure it will be observed that a sheet of ½ in. insulating board has been placed behind the waterway; the unit is now ready to receive the flat radiating surface. The plate will be affixed with screws and pulled tight against the bearing surface to reduce the resistance to heat flow.

Fig. 4 shows the same type of sections used in a ceiling and insulated with foil.

Fig. 5 shows a completed ceiling installation. A molding is visible around each hot plate; this is needed to insure an air tight connection between the plate and the surrounding unheated ceiling since, if there were leakage, dust streaks would appear on the unheated part of the ceiling radiating out from the hot panels.

A third type is similar to that just described, except that the metal plate has curved edges to permit fixing to wall or ceiling where flush installation is not possible. This type is particularly well adapted to use in revising the heating system of an existing structure. The plate edges are provided with a recess which is fitted with an asbestos packing material.

A fourth type, like the first described, is 100 per cent cast iron, but is constructed with an extended surface at the back of the plate and is usually installed so that air passes over the unexposed side of the plate and is thereby heated by convection. Eight vertical extended waterways are cast in every section and the resistance to heat flow is so small that the flat surface approaches a uniform temperature which is but slightly below the temperature of the heating fluid. A cross section through such a unit is shown in Fig. 6. This type is less expensive to install than others because the additional surface increases its actual heat dissipation rate to more than 3½ times that of a ceiling installed unit of like area and operating at the same surface temperature. However, the added capacity is all in convection and the actual radiant fraction of the total energy from such a unit is so small (below 20 per cent) that it might with some justice be said to resemble a convector more closely than a radiant panel. Its principal advantage is that the flat exposed surface lends itself to incorporation into the decorative scheme. Fig. 7 shows a typical wall application.

Application

Statistics are not available as to the number of existing installations using these panels, but there are more than 100 in Italy alone and many times that number in England. A conservative estimate of total European installations would be 500.

In conclusion, it is to be emphasized that panels of this type are not competitive with sinuous coil or electric fabric in the field of low temperature (90-100 F) ceiling panels. The first cost of the cast iron panels for such service would be in excess of $1.50 per 100 Btu per hr and (for panels exclusive of piping and boiler plant) would be prohibitive. But it is meaningless to even make such a comparison since the cast iron panel was never designed for operation under these conditions. When used in the temperature range for which they were designed, these panels provide a practical method of realizing some of the characteristics of radiant heating.

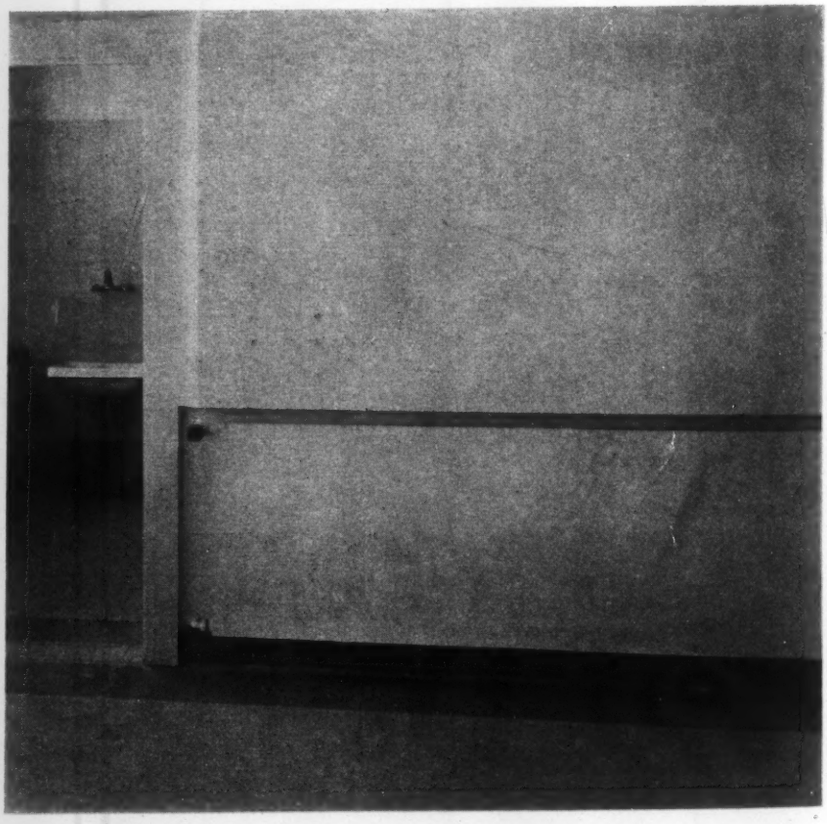
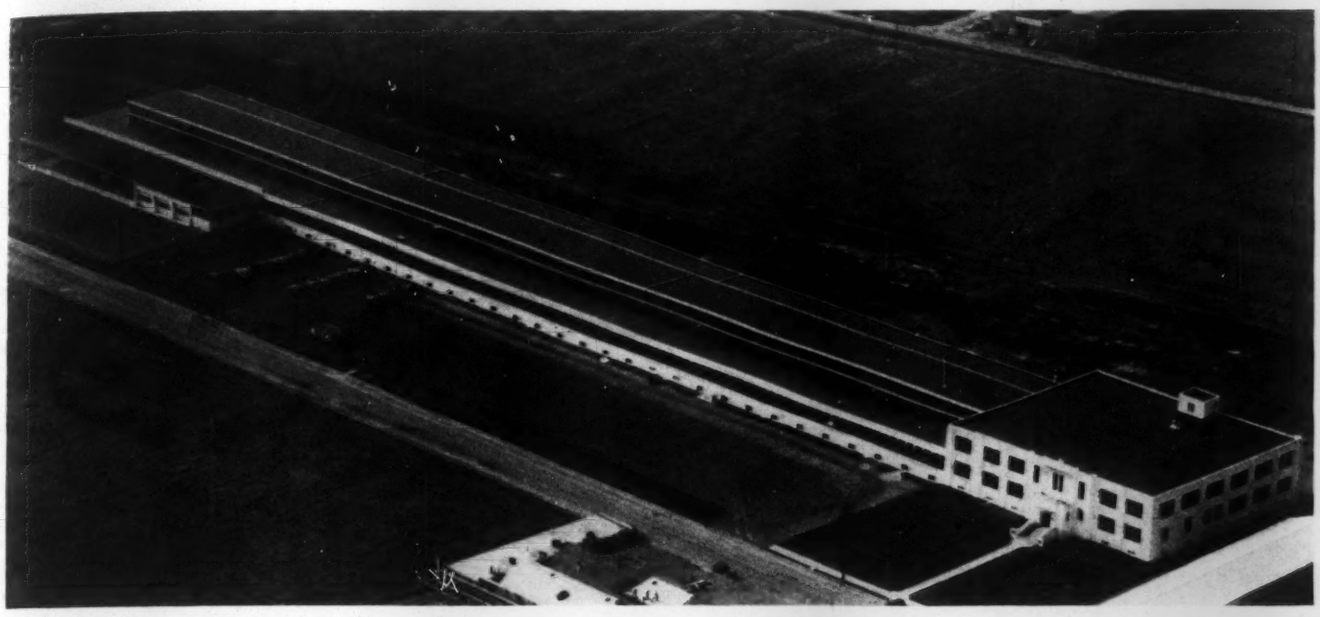


Fig. 7—Typical wall application of the unit illustrated in Fig. 6, showing how it fits into the general decorative scheme



Photograph of new Loose-Wiles Biscuit Co. bakery at Oakland, Calif., taken from an airplane at about 2000 ft elevation. Note the reflection of the elevator penthouse and monitor section steel sash in the water impounded on the roof of the building, and the areas in which the roof is zoned or ponded into sections, normally located (as mentioned in the text) at building expansion joints. The entire surrounding grounds are to be landscaped; the contract has been let but the rather persistent and "unusual" rainy weather in recent months has retarded this part of the building program

Flooded Roof, Double Pane Windows Assist in the Control of Air Conditions

M. C. Haley, Engineer, Loose-Wiles Biscuit Co., Explains Their Use at New "Sunshine" Bakery

SUMMARY—In addition to the design of the air conditioning plant itself, the air conditioning engineer must also consider ways and means of reducing the heat gain of a building for economy in air conditioning and to assist in the maintenance of proper temperatures. Among the means employed at the new Loose-Wiles bakery at Oakland, Calif., are flooding the roof with a pond of water, and the use of insulating and heat absorbing windows. Mr. Haley explains here the reasons for incorporating these features and describes the roof construction and the method of roof flooding used

IN order to reduce the air conditioning load and to aid in maintaining proper air conditions at the new bakery of Loose-Wiles Biscuit Co.—bakers of "Sunshine" biscuits—nearing completion at Oakland, Calif., use is made of a pond of water on the roof. For the same purpose, there is extensive application of double pane insulating windows for departments such as the sponge and proofing rooms where inside temperatures must be kept fairly uniform, and heat absorbing and glare reducing glass is used for all other windows, with the exception of those in the basement. There are over 15,000 lights of glass in the steel factory windows.

Ponded Roof

With reference to the ponded roof, there were several factors taken into consideration before deciding upon the final design adopted.

The building location is on ground only a few feet above high tide datum referred to San Francisco Bay, a short distance away from the plant. The storm drainage system surrounding the property is comparatively poor and the runoff from the rather large roof area into the existing storm sewer in the street would be excessive as the building is 960 ft long by 120 ft wide, thus comprising approximately 115,000 sq ft of roof area to drain. To conform with local plumbing ordinances, the roof leaders and drains without a flooded roof would normally approximate 10 to 12 in. in diameter and would have to extend to the far end of the building before picking up the storm sewer underground in the street. A further advantage of the flooded roof was that the steel and roof framing details and installation were simplified, inasmuch as the roof is entirely flat, thereby eliminating the need for all members and connections being cut on the bias.

The 2 in. x 8 in. matched pine roof sheathing was bolted and clipped directly to the roof steel purlins

and girders, all wood being well dried and seasoned and painted on all sides and edges to assist in eliminating moisture absorption and subsequent warping or movement of the roof sheathing. The roofing was then applied, and consists of one layer of 60 lb asbestos base felt, one layer of asphalt saturated fabric, and two layers of 20 lb asphalt saturated asbestos felt, cemented to the roof deck and to each other and surfaced with standard asphalt waterproofing cement. The roof areas are ponded into sections, normally at expansion joints in the building, by curbing and flashing over at these locations. In addition a curbing was built up about 6 in. high on the building wall sides and capped over with 10 ga alloy sheets preformed into a continuous ridge roll.

Roof Drains

In each ponded area, there is a special roof drain which maintains the water level to 2 in. When the upper section or sleeve is removed the areas are drained level with the roof. The roof drains are but 2 in. in diameter. Normally, in the winter, the roofs will be de-ponded after a heavy rainfall and then allowed to fill again, in this manner holding in check the runoff to the street storm sewers. Copper spillways along the building wall line are installed at intervals in the curbed sections up about 2½ in. from the roof level to serve as a safeguard and permit water to spill over if it ever reaches this particular height.

In the summer months, water from the water supply system and from the air compressor and allied equipment will be piped to the roof for filling these areas as required. Climatic conditions are not severe in this locality; however, in a few of the summer months it is believed that the normal evaporation of the water will provide a cooling effect within the building.

Advantage of Ponding

In a bulletin published by the Portland Cement Association on Concrete for Industrial Buildings and Garages, it is stated, in effect, that in roofs installed absolutely flat, drains and overflows are frequently placed 2 in. above roof level. As a result a sheet of water covers the roof practically all of the time. This helps to preserve the roofing and also by slow evaporation assists materially in cooling the story below the roof. With the roof sumps so designed to permit of easily deponding any section we believe such a roof has many favorable factors. Water may or may not be impounded on the roofs at any time and such an installation is quite flexible and we believe economical

and good practice. In colder climates freezing of the water may be objectionable; also, in warmer climates the impounded water may tend to heat if too thin a body of water is used and the results may not then be satisfactory.

In our particular case we confidently feel we have arrived at an economic and favorable solution to our several problems by using the flooded roof. Including the saving in plumbing piping, the ease and simplification of the roof fabrication and installation, together with the cooling effect obtained and the prolonged life of our roofing felts, we believe such an installation is soundly warranted—at least under similar working conditions as exist in this particular locality.

We do not believe these ponds of water will become quickly contaminated or provide a suitable place for the breeding of mosquitos, but if this does eventually result, the roof may be drained occasionally or the water may be chemically treated. If the water must be changed frequently it may be filtered and be re-used, or in some instances used for watering the surrounding landscaped areas, lawns, etc., or for other desired purposes.

Wall Construction

The building walls, up to the steel sash line, are of reinforced concrete monolithic construction with the basement concrete bearing walls. Above the steel sash a continuous spandrel of corrugated asbestos-cement sheets was installed, with the corrugations horizontal to the building lines. In this particular locality weather conditions are quite normal, and with but small variation in temperature due to its nearness to the bay and the prevailing winds blowing a large percentage of the time from that direction, we believe working conditions will be satisfactory and better than normal. In some of our recent buildings in the east we have gone to additional expense to insulate the building walls entirely with a wall construction consisting of an interior wall of encased insulation board, faced with a hard surface asbestos-cement veneer and an exterior wall of the corrugated asbestos-cement sheets.

The surfaces therefore have the permanence of stone and with this construction the equivalent insulating value of approximately 14 in. of masonry wall is attained through the use of a 1 in. core of insulating board which is securely bonded to the interior wall facing. As and when this additional insulation is required at our Oakland bakery, provisions have been made to readily install this insulation board on the interior face of the existing corrugated asbestos-cement sheets.

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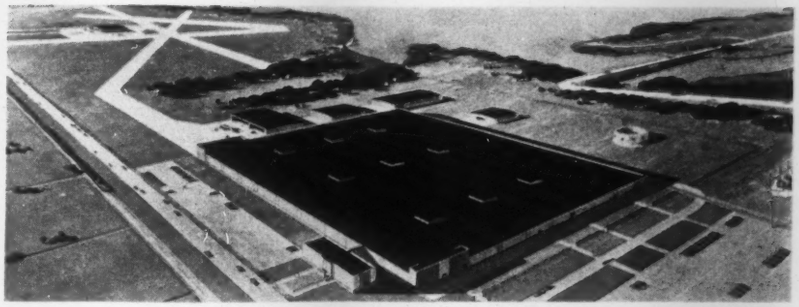
Comfortable Readers—Attendance at the Coalinga District Library, Fresno County, Calif., has jumped approximately 50 per cent since the installation of air conditioning. Librarian Howard M. Rowe, discovering that it was on scorching afternoons and sultry evenings that attendance showed the sharpest drop, decided to try air conditioning. A 10 ton air conditioning system supplying cooling for the library and its reading and studying rooms was therefore installed.

Many persons who hadn't been near the library for years returned as regular patrons. School students once more used it as a reference library. One of the contributing reasons for the pick-up in attendance is the reduction in street noises through the installation of inner doors for insulation purposes. Preservation of rare books through elimination of the "drying out" encountered previously as a result of the hot, dry air of Coalinga, also has been reported by Librarian Rowe since air conditioning.—Edward T. Murphy, Vice-president, Carrier Corp.

BLACK-OUT!



Defense Industry Plants Install Thousands of Tons Refrigeration for Air Conditioning

THE rôle of industrial plant air conditioning in the national defense program on which so much of our endeavor is being put these days has been pointed out in numerous articles published during the past year or two in HPAC. Controlled temperatures and humidities are essential to many production processes (some can't be carried on at all without air conditioning), and are often quite important to the maintenance of efficient working conditions for the personnel under the stress of the greater effort and longer hours required by the so-called "all out" effort. One particularly interesting application of air conditioning, to which special attention has been given in these pages, is the use of air conditioning in plants of windowless construction —that is, the "black-out" plants, which are so designed as a protection against possible attack from the air.

Thousands of tons of refrigeration for air conditioning defense industry plants is being installed this year. For instance, one of the automotive manufacturers, who is building three aircraft engine plants in three different midwestern cities, will install a total of almost 10,000 tons of centrifugal refrigeration for air conditioning. Other manufacturers are planning air conditioning on a similar scale.

An example of a "constant temperature" black-out defense plant containing no windows is the new Texas unit of North American Aviation, Inc. In a plant of this kind it is necessary to have artificial lighting closely simulating actual daylight conditions, and an air conditioning system.

Design Conditions

The air conditioning system is designed to provide a reasonable amount of comfort cooling during summer operations by circulated chilled water; heating will be handled in winter by circulation of warm water. In deciding upon the most advisable system for this plant the following design conditions were employed:

Summer Operations — Cooling outside air of 100 F dry bulb and 78 F wet bulb to produce an inside air temperature of 84 F dry bulb at a relative humidity not exceeding 45 per cent. While maintaining these conditions, not less than 160,000 cfm of outside air is to be infiltrated.

Winter Operations—Heating outside air of 5 F to produce an inside air temperature of 70 F dry bulb and with 35 per cent relative humidity. These conditions to be maintained during this period at which a maximum of 160,000 cfm of outside air is to be used.

Sensible and latent heat load was computed on the basis of 10,000 people occupying the plant at a given time. It was also necessary to figure on a considerable load due to fluorescent lighting and machinery and tools in operation. Design of the heating system was based on shut-down operations in which no set heat gain could be realized from either personnel or connected power.

2600 Tons Refrigeration

At present, the air conditioning layout comprises (a) four 650 ton centrifugal compressors for producing chilled water at approximately 45 F which is to be circulated to return type cooling coils in each of the nine penthouses situated on the roof of the main factory building; (b) nine penthouses containing dual systems of mechanical oil immersion type filters, the return type cooling coils and fan units; and (c) a mechanical forced draft cooling tower placed over a million gal reservoir situated south of the main factory building.

Supply air is taken from the exhaust side of each fan in each of the penthouses and distributed to the factory through suitable ducts which are suspended in the trusses above the bottom chord. Return air is taken from the factory through grille work at the bottom of each penthouse. Louvers under automatic control are provided in each penthouse for the infiltration of outside air.

Each fan has a maximum output of 62,500 cfm against estimated system resistance pressure of 1 in. of water.

Three of the 650 ton centrifugal compressors are direct connected to synchronous motors, the fourth being connected to an induction type motor for purposes of regulation. The forced draft mechanical cooling tower was designed to handle 10,000 gpm from an entering temperature of 100 F to a final temperature of 85 F at an atmospheric condition equivalent to 78 F wet bulb, and to lower temperatures according to a lower wet bulb reading. The loss by evaporation passing through the cooling tower is not to exceed 1 per cent of the total water circulated for

SUMMARY—Thousands of tons of refrigeration is being installed this year for air conditioning service in our national defense plants. One important reason for air conditioning is to make these factories "black-out-proof." . . . An example is a new 1 million sq ft aircraft plant in Texas, served by four 650 ton centrifugal refrigeration compressors. The air treating equipment is situated in nine penthouses, and the chilled water is circulated to them for cooling in summer. . . . The design conditions and air conditioning equipment are described in the accompanying text

These Texans are acquiring the skill required to fabricate and assemble aircraft to army standards. The photo was taken in one of the training rooms in temporary quarters of North American

each 10 deg reduction in water temperature, drift loss not to exceed 0.2 per cent of the total water circulated. Construction of the tower is such that it will withstand all stress produced by winds or other loads equivalent to a wind velocity of 100 mph or a pressure of 30 lb per sq ft without the use of guy wires. A maximum noise level of 85 decibels is required at a distance of 50 ft from any side of the tower.

This system was designed by C. J. Gallant, technical consultant of North American Aviation, Inc., and D. S. Capstick of the Frigidaire Division of General Motors in cooperation with J. Gordon Turnbull.

WAR DEPARTMENT APPOINTS SPECIALISTS

The war department announced last month the addition of several more prominent consultants and specialists in design and engineering to the staff of the construction division, office of the quartermaster general, which is in charge of the temporary emergency construction program for troop housing, powder factories, ordnance plants and miscellaneous facilities. Appointed by the chief of the construction division, with the approval of the quartermaster general, they are, with their respective assignments, as follows:

Warren H. McBryde, San Francisco; engineering branch; chief, mechanical engineering unit; to direct work on power generation and distribution, munitions plant design, cold storage and refrigeration, oil, gas and gasoline distribution, pipe lines, pumping stations and special mechanical installations.

Ernest B. Black, Kansas City, Mo.; engineering branch; to act as consultant on water supply and water distribution problems.

Samuel A. Greeley, Chicago; engineering branch; to advise on sewage treatment projects, sewer systems and incineration problems.

Richmond H. Shreve, New York City; engineering branch; to serve as architectural consultant.

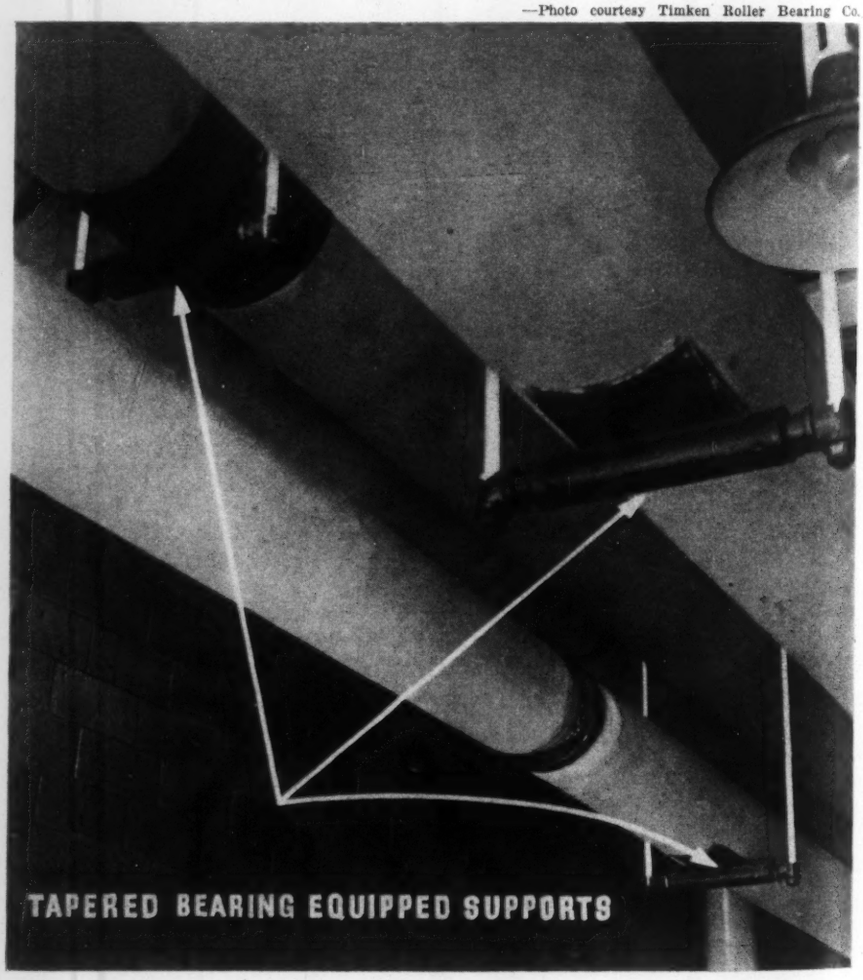
A. D. Taylor, of Cleveland; engineering branch; consultant, unit of site planning.

Alonzo J. Hammond, Chicago; construction advisory section; to join Brigadier-general George R. Spalding, (Ret) as fifth member of the committee which passes upon the qualifications of contractors applying for work under the construction division. By the appointment of Mr. Hammond, the construction advisory section is rounded out to the size originally contemplated when it was established.

PIPING RIDES ON ROLLER BEARINGS

The American Viscose Corp. has installed tapered roller bearing conveyor tubes as supports for their hot water lines at their Front Royal, Va., plant. The steam line supports in another American Viscose plant at Nitro, West Va., are similarly equipped. The bearing mounting consists of a conventional conveyor tube, 8 in. long, equipped with roller bearings and appropriate inner and outer seals at each end of the tube. Adjustment of the bearings is obtained through collars placed over the shaft and locked by means of two set screws. The bearings were packed at assembly with a light-to-medium consistency lime base grease. These are believed to be the first applications of this type. They provide assurance that line expansion will be properly handled, and the ease of rolling afforded by the bearings permits the pipe expansion to take place with minimum effort and precludes extraneous loads being put on the line by expansion and contraction

—Photo courtesy Timken Roller Bearing Co.



How to Save HEATING DOLLARS

H. P. Scott, Assistant Supervising Engineer of Large Real Estate Management Firm, Reports Examples of Big Savings in Heating Buildings

AFTER it is determined—by some such method as outlined in my article in the March HPAC—that the fuel consumption of a building is excessive, it may be reduced by reducing the building requirements and by increasing the plant efficiency.

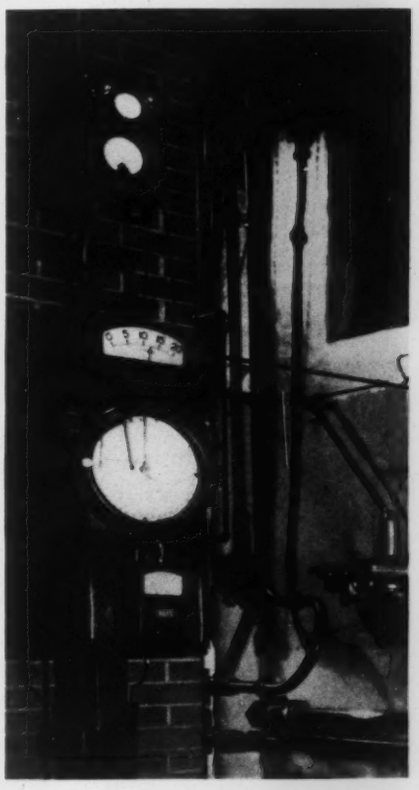
Reducing the heat requirements of the building can be accomplished by weatherstripping windows, entrances and elevator shafts; installing revolving doors; keeping valves and traps in good repair; discontinuing or reducing the steam entering unoccupied premises; providing automatic controls to retard steam as the demand decreases; by insulating all pipes not being utilized for radiation; etc.

Recommendations for improving plant efficiency are many and are fully discussed in numerous easily obtained articles. Briefly, sections of a building requiring longer hours of heat than the general building space should be served by separate risers, as extra risers, properly valved for controlling the flow of steam, are far less expensive than heating an entire building to care for a local demand. Quick venting air eliminators make lower working pressures possible and afford a rapid means of purging cold air from the system. Circulators and vacuum pumps provide for rapid circulation and conserve steam by decreasing the time element required to make the circuit of the radiators or hot water outlets. Agitators in the steam boilers create a mildly turbulent condition which promotes rapid steaming.

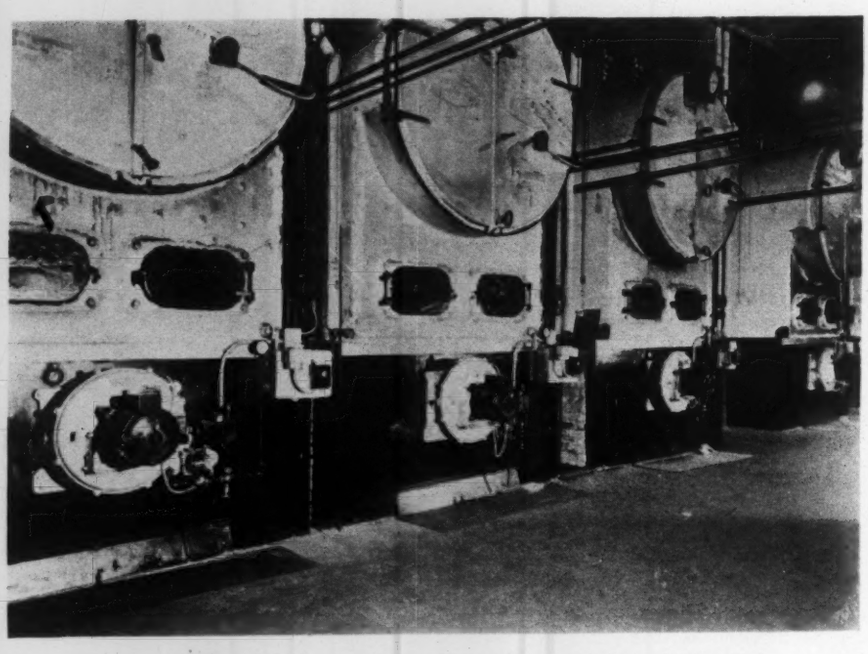
Since human nature shuns inconvenience, controls should be placed in easily accessible locations. Feedwater treatment, the judicious application of soot removing compounds and tube turbining keep heating surfaces free from scale, allow for the ready transfer of heat and inhibit the corrosion of the metal. Sludge solvents are proving not only beneficial for improving the flow of oil to burners and alleviating the clogging of strainers, pumps and nozzles, but are considered by many to be compulsory treatment for the more viscous grades of heavy oil now on the market.

Barometric dampers, draft controls and blowers adjust natural conditions to work in conjunction with plant design. Gages, meters and thermometers should be provided to furnish the engineer with an intelligent knowledge of what is taking place. Complaints due to insufficient heat should be immediately investigated and eliminated, not by forcing an excess of steam into the risers to counteract the deficiency but by locating and correcting the fault. In this day of generally reduced rentals and increased labor, material and taxation charges, it is the duty as well as the privilege of engineers and maintenance men to educate owners to the possibility

SUMMARY—**In March, Mr. Scott, who is assistant supervising engineer of Brown, Wheelock, Harris, Stevens, Inc.—large New York real estate management organization—told of a method whereby an overall reduction of 16 per cent in fuel consumption on a total annual fuel bill amounting to three-quarters of a million dollars has been achieved. He also presented a tabulation of fuel consumption factors for various types of buildings and various fuels based on a survey of 160 buildings using coal, 40 heated by street steam and 50 burning oil; these unit figures may be used to set up a mark at which to shoot. . . . This month he reviews some actual examples of how savings in heating dollars have been made. All methods of making such savings aren't of course covered, but the cases cited indicate many of the things to do, prove there are numerous possibilities. . . . In general, excessive fuel consumption for heating buildings can be reduced in two ways: by reducing the heat requirements of the building, and by increasing the plant's efficiency**



Gages, meters and thermometers should be provided to furnish the engineer with knowledge of just what is taking place



The apartment building served by these four boilers is divided into zones under the control of motor operated pressure reducing valves

of reducing the items charged against the furnishing of heat and hot water to their clients. Since the fuel item is one of the largest single charges which an owner is called upon to honor, a reduction of any size will be instantly appreciated.

Proof of the Pudding

Just as the "proof of the pudding" is in its consumption, records of fuel consumption have proved the value of applying theory to practice.

Thirty Story Apartment—A 30 story, 7½ million cu ft, 95 per cent occupied New York apartment house overlooking Central Park and exposed on three sides, was converted to oil heat in the fall of 1937. It was estimated that the four boilers, supplying hot water by means of instantaneous submerged coils, would annually consume ½ million gal of oil. This estimate was exceeded by 17 per cent the first season, although the entire plant was of good design and installation.

Due to the several exposures, a zoning system was recommended and installed, consisting of five divisions of supply, each activated by a motor operated pressure reducing valve, controlled by outside temperature and the steam requirements of a key radiator in each of the several zones. The efficiency of the burners was improved by the installation of a CO_2 recorder, draft gages and adjustors. Excess air was reduced from 120 to 40 per cent, CO_2 was raised from 7 to 11 per cent and the oil consumption reduced 14 per cent. Of this total saving, 9 per cent has been credited to the zoning system and the remaining 5 per cent to the instruments. The investment of approximately $4000 was returned from savings in two seasons.

Office Building—The management of a midtown 1¼ million cu ft office and loft building in New York was assumed in the spring of 1936. Due to a light hot water load and restricted hours of heating, a standard of 40 gal of fuel oil per 1000 cu ft per season was established. Although the tenancy at that time was 75 per cent of capacity the consumption for the first season was 20 per cent in excess of the selected standard. During the past few seasons cracks in the boiler setting have been located and sealed, a submerged hot water coil has replaced a steam heated tank coil, quick venting valves have been installed at the tops of all risers and new insulation has been applied to the two boilers. The working pressure has been decreased from 14 to 2 lb and, although the tenancy has since increased from 75 to 100 per cent, the fuel consumption has been reduced 17 per cent. This has amortized expense of the improvements.

Apartment—A 2¼ million cu ft apartment house on New York's upper Park Ave. was converted to oil in the fall of 1938. It was estimated that the annual oil consumption should not exceed 155,000 gal. This estimate proved correct within ½ per cent but it was believed that even this acceptable record could be bettered.

An automatic temperature control having a three point balance (inside, outside and radiator output temperatures) has reduced the consumption 5 per cent.

Apartment—Still another apartment dwelling exposed on three sides, 75 per cent occupied and having a cube of 1½ million cu ft had oil burners installed in the fall of 1936. A barometric damper, draft gages, submerged hot water coils and insulation reduced the first season's oil consumption 14 per cent. The plant is now operating 3 per cent below this.

Apartment—A coal burning, upper East Side, 1 million cu ft apartment house had its consumption reduced from 0.89 to 0.77 lb per cu ft per season due to the installation of a barometric draft control, submerged coils and new insulation. The reduction amortized the improvements in three seasons.

Loft Buildings—A 12 story downtown loft building, supplying heat only, from a rice coal burning "pork chop" boiler, showed a 24 per cent saving after quick venting valves at the tops of all risers made it possible to reduce the operating pressure from 9 to 1 lb and a damper regulator was installed to prevent this minimum requirement from climbing during the absence of the combination "fireman-elevator operator-porter." An equalizing line between the boiler water and steam sections, and a Hartford loop, eliminated the former tendency of the boiler water backing up the return lines and flooding the radiators on the 1st and 2nd floors.

A 1½ million cu ft downtown rice coal burning loft building showed a 13 per cent fuel reduction after defective asbestos was replaced on the boiler and mains.

Installing new radiator valves and repitching trapped branch lines resulted in an important but relatively small saving of 4 per cent in another 2½ million cu ft loft building.

A condensation pump and the insulation of risers saved 9 per cent in a Wall St. office building.

Identifying Piping Services

Color Legends for Plant and Building Piping

HPAC's readers frequently ask HPAC's editors for information on various methods of identifying piping systems in plants and buildings. Many supervising and operating engineers and maintenance men have found that a logical scheme of identifying piping services, together with drawings showing locations of the various lines, save time and money and often prevent costly mistakes.

With industrial plants working longer hours, less time for repair and maintenance operations, and—in many cases—new men on the job, an easily understood method of marking the piping systems becomes of increased importance. For this reason, various methods which have been explained in detail in previous issues of HPAC are brought together in this data sheet for handy reference and use.

There is available an American Recommended Practice Scheme for Identification of Piping Systems (A13-1928), copies of which may be had from the American Standards Association, 29 W. 39th St., New York, N. Y., at 50c each. Two of the tables from this standard are reproduced here; further information about it was given in HPAC, October, 1938, pp. 651-656.

Sizes of Stencil Letters

(From American Recommended Practice Scheme for the Identification of Piping Systems, A13-1928)

Outside Diam. of Pipe or Covering, In.	Size of Stencil Letter, In.	Outside Diam. of Pipe or Covering, In.	Size of Stencil Letter, In.
3/4	1/2	5	1 1/2
1	1/2	6	1 3/4
1 1/4	1/2	7	2
1 1/2	3/4	8	2 1/2
2	3/4	9	2 1/2
2 1/2	7/8	10	3
3	7/8	11	3
3 1/2	1 1/4	12	3 1/2
4	1 1/4	13 and over	3 1/2
4 1/2	1 1/2		

Classification of Materials Carried in Pipes

(From American Recommended Practice Scheme for the Identification of Piping Systems, A13-1928)

Material Piped	Physical State (Gas, Liquid, or Semi-Solid)	Temperature of Material in Deg. Fahr (Max.)	Pressure in Lb per Sq In. (Min.)	or	Vacuum in Inches of Mercury or Water	Classification
Acetic acid	Liquid	Normal	30 lb		28 in. Hg	D
Alcohol	Liquid	Cool				D
Amyl acetate	Liquid	Cool				D
Alum solution	Liquid					S
Acetylene gas	Gas	0 to 200	1/2 in. to 250 lb			D
Benzol	Liquid	Cold	Up to 80 lb			D
Brine	Liquid	Cold	About 60 lb			S
Butyl alcohol	Liquid	Cool				D
Bleach liquor	Solution					D
Bisulphite liquors	Liquid					D
Blau gas	Gas	0 to 200	1/2 in. to 250 lb			D
Compressed air	Gas	80	300 (in special cases 3000 lb)			S
CO_2	Gas and liquid	— 30 to — 100	0 to 250 lb per sq in. ga			D
Caustic soda solution	Solution					D
Chlorine	Gas, liquids, and solutions					D
Carbon bisulphide	Gas and liquid					D
Chloroform	Gas and liquid					D
Carbon tetrachloride	Liquid					S
Coal gas	Gas	0 to 200	1/2 in. to 250 lb			D
Dyes	Solution	Usually cool				D
Flue gas or waste heat	Gas	0 to 200	1/2 in. to 250 lb			D
Foamite	Liquid	Cold	Up to 100 lb			F
Glycerine	Liquid	Hot and cold	Up to 60 lb			S
HCl	Liquid	Up to 80	2 to 10 lb			D
Hydrogen	Gas					D
H_2S Gas	Gas	0 to 150	1/2 in. to 100 lb			D
Intermediates	Solution	Usually cool				D
Lactic acid	Liquid	Normal	60 lb		20 to 22 in.	V
Mixed acid	Liquid	Normal	30 to 80 lb			D
Miscellaneous solvent	Liquid	Cool				D
Mercury	Gas and liquid		29 in. to 100 lb			D
Muriatic acid	Liquid					D
Natural gas	Gas	0 to 200	1/2 in. to 250 lb			D
Nitric acid	Liquid	Normal	10 lb			D
Nitro bodies	Liquid	Cool	Up to 40 lb			D
NH_4NO_3 (molten)	Liquid		None			D
NH_3	Liquid and gas	— 30 to 100	0 to 250 lb per sq in. ga			D
N_2O and N_2O_3 vapor	Vapor	0 to 150	1/2 in. to 100 lb			D
Oils (Petroleum)	Liquid	Below 580	Below 1200 lb			D
Paper sizing solution	Liquid					S
Pinch gas	Gas	0 to 200	1/2 in. to 250 lb			D
Producer gas	Gas	0 to 200	1/2 in. to 250 lb			D
Pyrox compounds	Liquid	Up to 80				D
Paint	Liquid	Cold	30 lb			D
H_2SO_4	Liquid	Up to 180	30 to 80 lb			D
Soda ash solution	Liquid	Cold	60 lb			S
Sugar juices and syrups	Liquid	195 to 200	0 to 50 lb			S
Steam	Vapor	Below 212	Below atmos.			S
Steam	Vapor	212 to 800	Above atmos.			D
SO_2	Gas and liquid	— 30 to 100	0 to 250 per sq in. ga			D
Sulphur chloride	Gas and liquid					D
Turpentine	Liquid	Cold	Up to 80 lb			D
Toluene	Liquid	Cool	Up to 40 lb			D
Tar	Liquid					D
Varnish		Cold and hot	30 lb			D
Vapors of valuable materials not otherwise specified	Vapor	0 to 180	1/2 in. to 100 lb			D
Water	Liquid	Cold	Any pressure			S
		Hot	Any pressure			D
Water Gas	Gas	0 to 200	1/2 in. to 250 lb			D

Key to Classification: F—Fire Protection—Red. D—Dangerous—Yellow. S—Safe—Green. P—Protective—Blue. V—Extra Valuable—Purple.

Color Code Used at Aircraft Factory

STEAM: Wide white band. Narrow band in center: Superheated, black; saturated, green; exhaust, vermilion.

RECEIVER: Wide orange band. Narrow band in center: High pressure drip lines to Holly receiver or traps, black; Holly receiver to boiler or discharge line from traps, vermilion.

FRESH OR CITY WATER: Wide dark blue band. Narrow band in center: Cold fresh water (including water sealing piping of turbines, step bearing pipes), vermilion; warm fresh water (supply and return), discharge from hot well pumps to hot well, hot well to feedwater heaters, black.

BOILER (BOILER FEEDWATER, FEEDWATER HEATER TO BOILER DRUMS): Wide pompeian red band. No center band.

WASTE: Wide lead color band. Narrow band in center: Blow-off, low pressure drips, overboard discharge, overflow and other waste lines, black.

SALT OR RIVER WATER: Wide light green band. Narrow band in center: Suction to fire and condenser circulating pumps, none; discharge from condenser circulating pumps, black; discharge from condensers, vermilion.

BEARING OIL: Wide tan band. Narrow band in center: Supply to turbines and air compressors, black; return from turbines and air compressors, vermilion.

FIRE MAINS (DISCHARGE FROM FIRE PUMPS, SPRINKLER SYSTEMS): Wide vermilion band. No center band.

COMPRESSED AIR: Wide black band. No center band.

VACUUM: Wide yellow band. Narrow band in center: Black.

ELECTRIC CONDUITS: Color same as adjacent surface.

FUEL OIL: Wide tan band. Narrow band in center: Green.

GASOLINE: Wide brown band. Narrow band in center: Supply, yellow; return, blue.

DRAINAGE (WASTE LINES, DRAINAGE AND SEWER PIPING): Wide black band. Narrow band in center: Pink.

Note—Wide band is 18 in. long and narrow band in center is 6 in. long.

Color Code Used at Rubber Industry Plant

SPRINKLER LINES	Narrow red band
WATER LINES	Narrow black band
AIR LINES	Narrow green band
HUMIDIFIER	Wide yellow band. Narrow band in center; Water, black; air, green
POWER CONDUITS	Narrow blue band
LIGHTING CONDUITS	Narrow brown band
OIL LINES	Narrow maroon band
STEAM	Narrow aluminum band

Color Code Used at Public Building

WATER: Wide blue band. Narrow band in center: High pressure, black; fire system, red; boilerfeed, brown; city pressure, none; drinking (cooled), white; hot, yellow; hydraulic supply, green; hydraulic return, gray.

STEAM: Wide white band. Narrow band in center: High pressure, red; low pressure, none; exhaust, green; vacuum return (cond.), black; vacuum return (water), blue; blow-off line, yellow.

AIR: Wide yellow band. Narrow band in center: Compressed, none; vacuum, black.

WASTE: Wide brown band. Narrow band in center: Sewage, red; storm water, white; drainage, none.

ELECTRIC LINES: Wide black band. Narrow band in center: Light and power, none; telephone, cream.

GAS AND OIL: Wide red band. Narrow band in center: Fuel oil, black; city gas, none; "Freon," white.

Note—Wide band is 8 in. long and narrow band in center is 3 in. long. Bands to be placed on discharge side of all valves and fittings.

In this standard, it is pointed out that the principal requirements for a standard scheme for the identification of piping systems are distinguishability, flexibility, inclusiveness, simplicity, practicality and rationality. Its first and principal requirement is that the pipes in each system shall be so colored as to designate exactly which of the five major classes of fluids (see table) are being conveyed by the system.

This scheme provides that the color may be applied over the entire length of the piping system or in bands 8 to 10 in. wide near valves and at other important places. The use of bands permits of identification by color, even though all the pipes of a given layout are given uniform treatment for purposes of illumination or decorative appearance.

Where it is desired to identify more exactly the nature of the fluids in a given piping system, this may be accomplished by the addition of one or more stripes of color at the edges of the band, or by stenciled letters, words or figures on the band. For example, in a plant having several safe materials, there would be several pipes having the dominant color or color band of green, and superimposed on these green bands on one piping system might be a stripe of red, on another a stripe of yellow, another a stripe of blue, etc., the color of the secondary stripe having lost its main classification significance under this scheme.

If the selected system had included legends instead of stripes, then in the example given above there would be superimposed upon each green band the stenciled name of the material conveyed by that particular pipe, or an identification mark of some kind.

In addition to this standard scheme for identifying piping systems, many plants and buildings have worked out their own color codes to meet their own special requirements. Three examples are tabulated here. The instructions accompanying the code for an aircraft factory read in part as follows:

All pipe lines to equipment shall be painted to 5 ft above floor the same color as the machines to which they are attached or the same color as adjacent walls if not connected to machinery.

The service of each piping system is to be identified by different colors, the proper painting of the flanges, or by stripes as indicated in the table.

All stripes shall be painted on the pipes or insulation at right angles to the center line and the edges shall be sharp and clean.

On pipes passing through floors identify by painting above and below each floor, except below ground floor.

On pipes passing through walls and partitions identify by painting on each side, except beyond outside walls.

On long runs of piping identify in conspicuous locations about 50 ft apart.

Identity painting may be located at other points as considered advisable for correct identification of the piping systems.

Heating·Piping·Air Conditioning

AMERICAN SOCIETY of HEATING and VENTILATING ENGINEERS

Journal Section

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A Comparison of the Weight, Particle Count and Discoloration Methods of Testing Air Filters

By Frank B. Rowley* and Richard C. Jordan**
Minneapolis, Minn.

This paper is the result of research sponsored by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS and the Graduate School of the University of Minnesota in cooperation with the Engineering Experiment Station, University of Minnesota.

Part 1

THREE fundamentally different test methods based on weight, particle count, and discoloration have been developed for use in the laboratory rating of air filters. The weight arrestance or efficiency indicates the percentage of the weight of dust in the air which the filter is capable of removing. The particle count arrestance shows the percentage of the number of dust particles which the filter can remove. The discoloration arrestance is a measure of the relative reduction in the potential soiling properties of the air-dust mixture caused by passing it through the filter. Thus, each test method measures a different property, and a filter subjected to all three tests will have three different arrestance or efficiency ratings. Furthermore, any single test method can be used in conjunction with any one of a number of different artificial test dusts possessing different physical and chemical properties, with each dust giving different test results.

In 1933 the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS incorporated the weight principle of testing air filters in their Standard Code for Testing and Rating Air Cleaning Devices used in General Ventilation Work. Several standard dusts have been prepared[1] for use in conjunction with this test method, and several articles[2, 3, 4] dealing with the various factors affecting the test results obtained by the weight method have been published. However, the weight test has never received unanimous acceptance by either the filter manufacturers or those individuals interested in filter rating methods, especially since the advent and development of the discoloration test method. For this reason there has been a need for extended studies covering a direct comparison and correlation of these three test methods. The present investigations cover the following points:

1. Factors affecting the results obtained by the discoloration test method.
2. Comparison of the weight, particle count, and discoloration methods of test on typical filters with various test dusts.
3. Correlation of filtering theory with test results.

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SUMMARY

Relative merits of three filter test methods based on weight, particle count, and discoloration are analyzed and the test results are correlated with the theory of filtering air. The particle count method of testing filters in its present state of perfection seems to require too long a time to make a determination which can be considered statistically reliable. The discoloration method is probably the best measure of the reduction in discoloration, while the weight method is the best measure of the reduction of the larger visible dust particles

Weight Test Method

The weight or crucible method of determining filter arrestance as used in these investigations was essentially that described in the ASHVE Air Filter Code.[5] The test apparatus and procedure have been described in a previous paper.[6] The rate of dust feed was 40 g (grams) per hour and the face air velocity 300 fpm. In the majority of tests determinations were made only of the arrestance, as filter life is the same by all three test methods.

Particle Count Method

The particle count method of determining filter arrestance consists in removing air samples simultaneously from upstream and downstream of the filter and determining by microscopic examination the number of particles per unit volume of air. Equation (1) can then be used to determine the arrestance:

$$\text{Arrestance} = 1 - \frac{P_2}{P_1} \quad \ldots\ldots\ldots\ldots (1)$$

where, P_2 = dust count downstream of filter, particles per cubic foot.

P_1 = dust count upstream of filter, particles per cubic foot.

In the present investigation these air-dust samples were collected by

[1] A Standard Air Filter Test Dust, by F. B. Rowley and R. C. Jordan. (ASHVE TRANSACTIONS, Vol. 45, 1939, p. 681.)

[2] Air Filter Performance as Affected by Kind of Dust, Rate of Dust Feed and Air Velocity through Filter, by F. B. Rowley and R. C. Jordan. (ASHVE TRANSACTIONS, Vol. 44, 1938, p. 415.)

[3] Air Filter Performance as Affected by Low Rate of Dust Feed, Various Types of Carbon, and Dust Particle Size and Density, by F. B. Rowley and R. C. Jordan. (ASHVE TRANSACTIONS, Vol. 45, 1939, p. 339.)

[4] The Effect of Lint on Air Filter Performance, by F. B. Rowley and R. C. Jordan. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, January, 1940.)

[5] ASHVE Standard Code for Testing and Rating Air Cleaning Devices used in General Ventilation Work. (ASHVE TRANSACTIONS, Vol. 39, 1933, p. 225.)

[6] Loc. Cit. Note 2.

two different methods; *first,* by means of an adhesive impingement type of dust counter developed in the University of Minnesota, Engineering Experiment Station, for use in making atmospheric dust count determinations; and *second,* by means of dust settling chambers. The dust counter used, shown in Fig. 1, consists of a suction pump which draws the air-dust mixture through a small orifice and impinges it against a glass slide coated with a thin film of oil. During sampling a vacuum is maintained in the impingement chamber at approximately 5 in. of mercury by means of the pump. The impingement slide carriage is linked to the pump handle so that during operation the slide moves slowly past the orifice. Thus, the jet of air and dust is impinged at constant velocity against the oiled slide, and the dust particles are deposited along a path. By microscopic examination of this path at 100 diam magnification the number of particles per unit volume of air can be determined.

The settling chambers used in these tests were similar to those described by Green.[7] In the present investigation the chambers were 4 in. x 4 in. in cross-section and 2 in.

[7]Some Accurate Methods of Determining the Number and Size Frequency of Particles of Dusts, by H. L. Green. (*Journal of Industrial Hygiene,* Vol. 16, January, 1934, p. 29.)

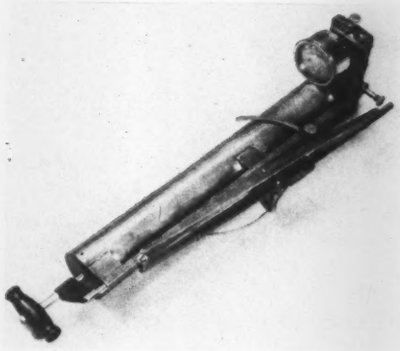


Fig. 1—Dust counter used in making particle count arrestance determinations

in height. Samples of the air-dust mixture to be analyzed were trapped in these chambers and the dust allowed to settle out of the air for 24 hours onto oil-coated glass slides placed on the chamber bottoms. By microscopic examination and count at 100 diam magnification the number of particles per unit volume of space was determined. The settling time was sufficient to insure complete removal from the air of all suspended particles visible at this magnification.

It was found impractical to use a high rate of artificial dust feed to the filters when making particle count arrestance determinations because of the resulting extremely high dust counts. Therefore, these tests were conducted with either normal air-borne dust and no artificial dust feed, or by dusting the air in the vicinity of the test duct inlet with the desired artificial dust. This dusting was accomplished about 10 ft away from the duct entrance by means of a compressed air jet and a small container of the test dust. In this way it was possible to obtain concentrations sufficiently low that they could be readily counted yet high enough that their mixture with the normal air-borne dust did not introduce any appreciable error. As the upstream and downstream samples were taken simultaneously, small variations in the dust concentrations had no appreciable effect on the results.

In making both the settling chamber and the dust counter arrestance determinations five samples taken from each side of the filter were counted and averaged for a single arrestance determination. The arrestance results reported are the average of five separate determinations or tests.

Discoloration Test Method

The discoloration method (also sometimes termed photo-electric cell, optical density, or soiling-power method) of determining filter arrestance consists essentially in removing air samples simultaneously

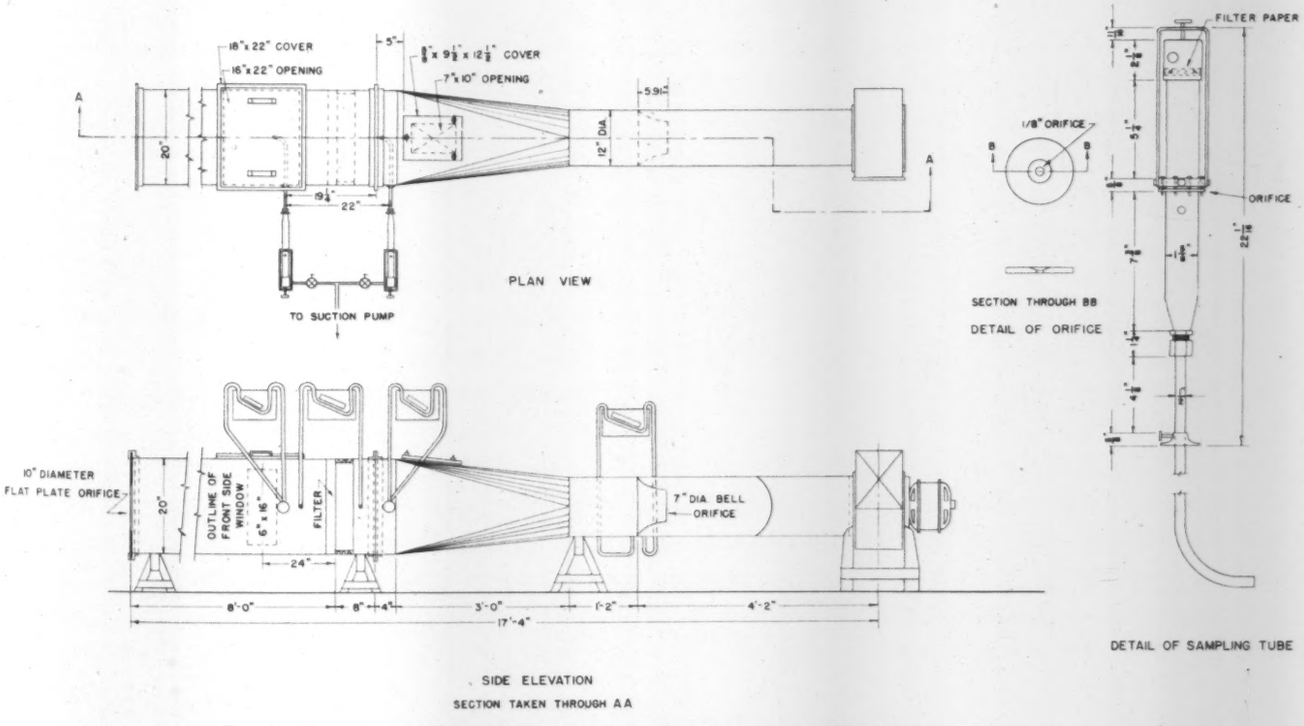


Fig. 2—Test duct with sampling apparatus for determining discoloration arrestances

from upstream and downstream of a filter, passing these samples through filter papers to remove the dust, and then subjecting these papers to a light beam and photo-cell to determine the concentrations of the dust deposits. The arrestance is determined by application of Equation (2).

$$\text{Arrestance} = 1 - \frac{C_1}{C_2} \quad \ldots\ldots\ldots\ldots (2)$$

where, C_1 = downstream dust concentration.

C_2 = upstream dust concentration.

The density of dust on the filter paper D will vary with the area, the rate of sampling, the concentration, and the time of sampling as in Equation (3):

$$D = \frac{QtC}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where, Q = volume of air sampled, cubic foot per minute.

t = time of sampling, minutes.

A = area of dust deposit, square inch.

C = concentration of dust in air stream.

D = density of dust deposit on filter paper.

If Equation (3) is solved for C then,

$$C = \frac{DA}{Qt} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

This expression may then be substituted in the arrestance equation, giving

$$\text{Arrestance} = 1 - \frac{D_1 A_1 Q_2 t_2}{D_2 A_2 Q_1 t_1} \quad \ldots\ldots\ldots (5)$$

In order to apply this relationship in practice three of the four variables D, A, Q and t should be kept constant and the other varied. As it is difficult to measure D in absolute units but is comparatively easy to determine when D_1 and D_2 are equal, this variable is usually adjusted so that D_1 and D_2 cancel.

The apparatus used in the present investigations was essentially the same as that developed and described by Dill[8] and used at the National Bureau of Standards. However Dill in his tests made

$$D_1 = D_2$$
$$t_1 = t_2$$
$$Q_1 = Q_2$$

and thus,

$$\text{Arrestance} = 1 - \frac{A_1}{A_2} \quad \ldots\ldots\ldots (6)$$

In this case the size of the filter paper spot is varied by providing various apertures corresponding to the different arrestances. In order to provide more flexibility in the tests of the present investigations the apparatus was modified so that,

$$D_1 = D_2$$
$$t_1 = t_2$$
$$A_1 = A_2$$

and thus,

$$\text{Arrestance} = 1 - \frac{Q_2}{Q_1} \quad \ldots\ldots\ldots (7)$$

Thus in these tests the volumes of air sampled from the two sides of the filter were varied until the resulting dust spot densities of the filter papers were equal.

Fig. 2 shows the test duct with the sampling tubes in position and a detail of these tubes. The air samples were drawn from the test duct by means of a suction pump and the volumes of these samples measured by means of calibrated flat plate orifices located in the sampling tubes. The pressure differentials across these orifices were measured by means of inclined draft gages. The rate of sampling for the downstream tube was 0.75 cfm and the upstream rate was varied, depending on the arrestance. The time of sampling varied from two to ten minutes, depending upon the nature and color of the test dust. The photometer circuit used for determining when the densities of the filter paper dust deposits were the same was identical with that used by Dill and originally described by Wood.[9]

There are several methods by which the photometer can be used to determine when the dust-spot densities of the filter papers are equal. The method originally described by Dill placed the filter paper dust spot between the light source and the photronic cell, and thus measured the intensity of light transmitted by the filter papers. In addition to arrestances determined by this method, the present investigations also include arrestances determined by measuring the light reflected from the surfaces of the filter papers. Fig. 3 shows the apparatus used for making transmitted light discoloration arrestance determinations, and Fig. 4, the apparatus for making reflected light discoloration arrestance determinations. In the latter case both the incident and reflected light beams were at angles of 45 deg to the filter paper surface, and at 90 deg to each other.

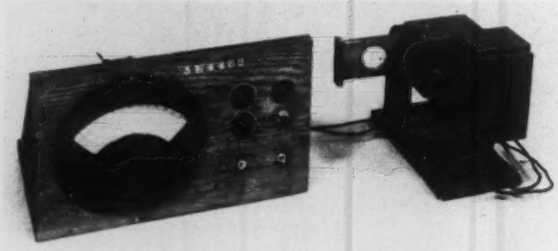


Fig. 3—Photometer for transmitted light discoloration arrestance determinations

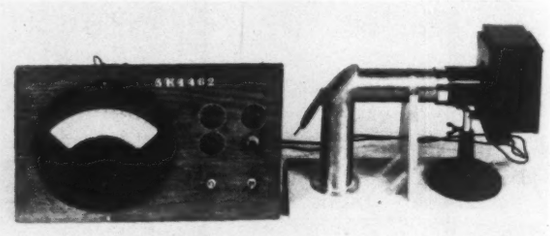


Fig. 4—Photometer for reflected light discoloration arrestance determinations

Factors Affecting Discoloration Test Results

During the course of the investigations it was found that several factors influenced the arrestances determined by the discoloration test method. Each of these factors was subjected to further analysis and will be discussed in turn.

Velocity of Air through Sampling Tubes

At the beginning of the investigations it was realized that when the sampling tube air volumes are varied in order to obtain equal discolorations of the upstream and downstream filter papers, there are

[8] A Test Method for Air Filters, by R. S. Dill. (ASHVE Transactions, Vol. 44, 1938, p. 379.)

[9] Zero-Potential Circuit for Blocking-Layer Photo-cells, by L. A. Wood. (*The Review of Scientific Instruments*, Vol. 7, March 1936, p. 157.)

necessarily concomitant variations in the sampling tube air velocities. This results in two possible conditions, one in which the sampling tube air velocity is greater than the duct air stream velocity, and the other in which the tube velocity is lower than the duct velocity. With the latter condition there is no apparent reason why the air-dust mixture samples should not be representative of those at the point of sampling, but when the tube velocity is greater than the duct velocity, not only the jet of air directly in front of the tube is being sampled, but also air surrounding this core. It would then appear that, since the flow of air-dust mixture must change directions in order to enter the sampling tube, some of the dust may be centrifuged out of the air stream and not taken into consideration. In order to determine the possible magnitude of this source of error a series of filter tests was run in which the sampling velocities were varied. In some cases the opening sizes of the sampling tubes were changed by the application of two tips, one large and one small, placed over the ends of the main sampling tube. The large tip was 0.667 in. in diameter, and the small one 0.182 in. in diameter, and both were 3 in. in length. These permitted extreme entrance velocity variations without any change in air volume. Normally the highest velocity used is approximately 718 fpm, with a duct air velocity of 300 fpm. In these tests the velocity was varied between 2,990 and 256 fpm.

The results of these tests indicated that any errors in the test results introduced by normal variations in the sampling velocities were negligible. For example, one filter tested three different times with downstream tube air velocities of 718 fpm, 574 fpm, and 383 fpm showed identical results. Only when the sampling tube velocities were increased to three or four times normal was there any significant change in the resulting filter arrestance. For example, on one sample when the upstream sampling tube air velocity was increased from 536 fpm to 2,990 fpm the transmitted light discoloration arrestance also increased from 25 to 28 per cent.

Selective Filtering

As some types of dust are more easily removed from the air than others, and large dust particles are more easily eliminated than small ones, most air filters exhibit the phenomenon of selective filtering. As a result dust samples drawn from either side of a filter and deposited on filter papers may exhibit the same photronic cell response to either reflected or transmitted light and yet appear different in color to the human eye. This was noticeable in discoloration tests in which the artificial test dust was either a mixture of two different dusts (such as a mixture of 80 per cent Pocahontas ash and 20 per cent carbon dust) or a single component dust of screened ash (such as Pocahontas ash). In the case of the mixed dust this was probably caused by a higher filtering efficiency for one of the components than for the other, thus resulting in a different mixture leaving the filter than that fed to the filter. In the case of the tests made with straight ash dust it appeared that there was always some carbonaceous material in the ash which again would result in a selective filtering and a visible difference in the appearance of the matched papers. The only cases in which the photronic cell matched papers also appeared perfectly matched to the human eye were those in which single component dusts relatively free from any impurities of a different color were used. Those dusts tested which most closely fill these requirements were carbon dust and Cottrell ash.

Papers Matched by Transmitted and Reflected Light

As previously noted discoloration arrestance determinations were made by two different methods, one in which the dust deposits on the filter paper were considered to be of equal density when the photronic cell response to light transmitted through these papers was the same, and the other when the photronic cell response to light reflected from the surfaces of the papers was the same. These two methods of test gave entirely different arrestance determinations, as dust deposits matched by one method were not matched by the other method. The results of these comparative tests will be presented later in the paper.

It appears that if air filter arrestance ratings are to be based upon the relative discoloration powers of air-dust mixtures before entering and after leaving the air filter that the measure of this discoloration should be in direct relation to the response of the human eye. As all surface discolorations observed by the human eye are received by reflected light it seems justifiable that this principle should also be used in measuring the discoloration of the filter papers.

As discoloration is usually defined in terms of the human eye's response, theoretically the most accurate results will be obtained when the spectral sensitivity of the photronic cell is equivalent to that of the human eye. The ordinary photo-electric cell is considerably more sensitive than the eye in the long and short wave length regions of the visible spectrum, and furthermore its sensitivity extends into the infra-red and ultra-violet regions. In order to determine what effect this had on the reflected light discoloration arrestance determinations several tests were run in which a correction filter was applied to the photronic cell in order to duplicate the spectral sensitivity of the human eye. There were no noticeable differences in the results obtained with and without this correction filter with the test dusts and light source used in these investigations, but it is conceivable that this might not always be the case.

Sensitivity of Discoloration Test Apparatus to Variations in Sampling Rate

The sensitivity of the photometer in detecting variations in the volumes of air sampled is dependent upon the amount of dust deposited on the filter papers. If the dust concentrations on the papers are heavy, additional dust deposits may result in little change in the photocell response. For this reason tests were made with both transmitted and reflected light to determine the change in photometer readings per unit increase in dust deposit, and from these tests it was possible to deduce the optimum time of sampling for maximum sensitivity. Fig. 5 shows typical response curves for

carbon dust, Pocahontas ash, and a mixture of 80 per cent Pocahontas ash and 20 per cent carbon dust. These tests were made at a sampling rate of 0.75 cfm and an air-dust concentration of 1 g of dust in 1250 cu ft of air. As would be expected, the darker the color of the dust the more rapidly the meter reading dropped off. These curves indicate that when carbon dust is used as a test dust, the time of sampling should be 1 to 2 min, whereas, with Pocahontas ash the sampling time might be increased to as much as 4 or 5 min. If in the case of the carbon dust the sampling time was increased to 3 min or more, the photometer response would be approaching a minimum, and it would be difficult to detect slight changes in the sampling rate. The response curves for transmitted light are similar to those shown in Fig. 5 for reflected light with the exception that the photometer readings approach zero when the dust deposits are heavy enough to completely block out all transmitted light instead, as in the case of the reflected light, of approaching a constant photometer reading greater than zero when the papers are completely coated with the test dust.

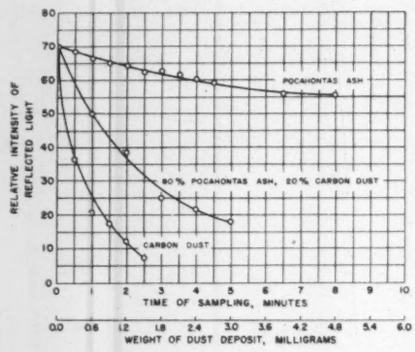

RELATIVE INTENSITY OF REFLECTED LIGHT
POCAHONTAS ASH
80% POCAHONTAS ASH, 20% CARBON DUST
CARBON DUST
TIME OF SAMPLING, MINUTES
WEIGHT OF DUST DEPOSIT, MILLIGRAMS

Fig. 5—Effect of dust deposit weight on intensity of reflected light

Relative Soiling Power of Different Test Dusts

Both the transmitted and reflected light methods of determining filter arrestance actually measure the reduction in soiling power or discoloration only in relation to the test dust being used. Thus, it is possible for a filter to show the same arrestance when tested on either a dark dust or a light colored dust, although the absolute soiling power of the dark dust per unit volume or weight would be many times greater than that of the light colored dust. Thus, it is conceivable that a filter tested by either the transmitted or reflected light methods might pass 80 per cent of a light colored dust on one test and 20 per cent of a dark colored dust on another, and yet this 80 per cent might not have nearly the potential soiling power that the 20 per cent of the dark colored dust would have. The variations in the absolute soiling powers of three different test dusts are indicated by Fig. 5, in which the reflected light photometer response is shown for identical dust deposits of Pocahontas ash, carbon dust, and the 80-20 mixture. Thus, for example, with a dust deposit of 1.6 milligrams the 80-20 mixture reflects 4.5 times and the Pocahontas ash 9 times as much light as the carbon dust. The necessity for a standard test dust to be used in conjunction with discoloration tests is apparent from these considerations.

Part 2

Comparison of Test Results

Weight, Particle Count and Discoloration Methods

It is apparent that filter test results obtained by the three methods (weight, particle count, and discoloration) will not be the same, as each method measures a somewhat different characteristic of the filter. In order to obtain a direct comparison of filter performance with different types of dust and with the three methods of test, four filters were selected as typical of those used in practice and were subjected to comparative tests. These filters were designated by the letters, *A*, *B*, *C*, and *D* and briefly may be described as follows:

A—A permanent type of cleanable oil filter 4 in. thick with 24 layers of expanded metal and wire screen graded from coarse mesh at entrance to fine mesh at leaving side.

B—A viscous coated throw-away type filter 2 in. thick. The fibrous media were graded in fiber size, density, and oiling from entering to leaving side.

C—A cellular type filter 2 in. thick built in two sections, each with the axis of cells set at 45 deg to the center line of duct and at 90 deg to each other. The cells on the entering side were of larger dimensions than those on the leaving side of the filter.

D—A filter of cotton media of coarse material on the entering side and glazed on the leaving side. The filter media were accordion plaited in frame to give an area of approximately 12 times the cross-sectional area of air stream.

These filters were selected because they were typical of their classifications. It should not be construed that they are necessarily superior to other filters of similar design.

Four synthetic dusts were selected for use in these comparative tests, namely: Pocahontas ash, screened through 200 mesh; Cottrell ash, screened through 200 mesh; Double Bolted Carbon Dust[10] screened through 100 mesh; and a mixture consisting of 80 per cent Pocahontas ash and 20 per cent carbon dust by weight. In addition to tests on these synthetic dusts some discoloration and particle count arrestances were obtained using normal air-borne dust without any artificial dust feed.

Filters *A*, *B*, *C* and *D* were all tested by the transmitted light discoloration and the weight methods on Pocahontas ash, Cottrell ash, carbon dust, and the 80-20 dust mixture. Reflected light discoloration arrestances were obtained on all filters with Pocahontas ash, carbon dust and the 80-20 mixture. In addition all four filters were tested by both the transmitted and reflected light discoloration methods using normal air borne dust. Particle count arrestances were determined for Filters *B*, *C*, and *D* by both the dust counter and settling chambers on normal room air dust suspensions and with the settling chambers using Pocahontas ash dusted near the duct inlet.

[10]Loc. Cit. Note 1.

Table 1—Comparison of Arrestances by Weight, Discoloration, and Particle Count Methods

Test Dust	Arrestance, Filter *A*					Arrestance, Filter *B*					Arrestance, Filter *C*					Arrestance, Filter *D*				
	Wt.	Particle Count		Discoloration		Wt.	Particle Count		Discoloration		Wt.	Particle Count		Discoloration		Wt.	Particle Count		Discoloration	
		Dust Counter	Settling Chamber	Trans. Light	Reflected Light		Dust Counter	Settling Chamber	Trans. Light	Reflected Light		Dust Counter	Settling Chamber	Trans. Light	Reflected Light		Dust Counter	Settling Chamber	Trans. Light	Reflected Light
Pocahontas Ash	93		—	25	51	96		33	36	48	85		22	18	30	90		40	48	67
Cottrell Ash	93		—	25	—	95		—	44	—	83		—	19	—	88		—	48	—
80 per cent Pocah. 20 per cent Carbon	85		—	7	37	88		—	32	47	72		—	4	24	99		—	53	63
Carbon Dust	45		—	10	37	63		—	33	54	33		—	10	9	84		—	71	71
Normal Air-Borne Dust	—	—	—	3	11	—	16	16	3	12	—	7	12	3	9	—	23	27	10	16

The results of these tests are shown in Table 1 and in the bar diagrams of Figs. 6, 7, 8, and 9, and indicate a wide variation in arrestances dependent upon both the type of test dust and the test method. In all cases the weight arrestances are higher than either the transmitted or reflected light discoloration arrestances or the particle count arrestances. In practically all cases the relative arrestances obtained by the different methods of testing were in the following order ranging from highest to lowest: weight arrestance, reflected light discoloration arrestance, transmitted light discoloration arrestance, and particle count arrestance.

In this ranking the dust counter and settling chamber arrestances have been grouped together under particle count arrestance as there are no fundamental differences between these two determinations. The only reversals in order were between the discoloration and the particle count test methods for Filters *B* and *D* on normal air and for Filter *C* on Pocahontas ash, and between the reflected and transmitted light discoloration methods for Filter *C* on carbon dust. Two of these four reversals were on normal air-borne dust and since, in these cases, all of the arrestances were low and grouped together with little spread, and the rate of dust feed was necessarily too low for good accuracy on the discoloration tests, these reversals were probably not reliable and were not used in determining the rank in relative arrestance for the different methods.

In the particle count arrestance tests made on the various filters with normal air-borne dusts, results obtained with the settling chambers check reasonably well with those obtained by means of the dust counter. Both of these methods required a large number of tests in order to obtain a statistically accurate average arrestance. The discrepancies noted between the two methods of test were well within the range of experimental error. The particle count arrestance tests made on Filters *B*, *C*, and *D* with the settling chambers showed much higher arrestances when the test air was dusted with the 200-mesh Pocahontas dust than when normal laboratory air was used. This result would be expected in view of the larger particle size of the artificial dust.

It is interesting to note that for Filters *A* and *C* on transmitted light, and Filters *B* and *D* on reflected light, the discoloration arrestances are higher for both the carbon dust and the Pocahontas ash tested separately than for the 80-20 mixture of the two components. It is difficult to offer a satisfactory explanation for this without further investigation, but it may be linked to the selective filtering phenomenon previously discussed or to a change in the physical characteristics of the aggregate over those of either of its constituents.

Both the discoloration and the particle count arrestances made using normal air dust suspensions showed extremely low results on all filters. This was probably caused by the higher ratio of the number of small particles to the number of large particles for the normal air-borne dust in comparison with the same ratio for the artificial dust. Filter *D* showed the highest arrestances by all test methods when using these normal dust suspensions.

The following conclusions may be drawn from these investigations:

1. For the majority of tests the relative magnitude of the filter arrestances determined by the weight, particle count, and discoloration methods were in the following order ranging from highest to lowest: weight arrestance, reflected light discoloration arrestance, transmitted light discoloration arrestance, and particle count arrestance.

2. The particle count arrestances determined by the dust counter method checked well with those determined by the settling chamber method. However, both methods required that a large number of tests be made in order to obtain a statistically accurate average determination.

3. Tests made by using normal air-borne dust resulted in the lowest arrestance values with each of the test methods. This was probably caused by the greater percentage of very small particles found in normal air-dust suspensions than in

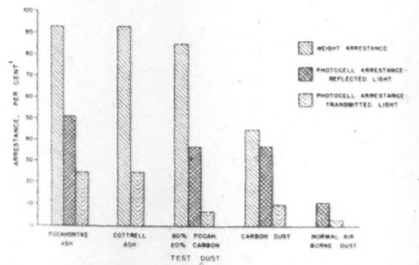


Fig. 6—Comparison of weight and discoloration arrestances for Filter *A* with various test dusts

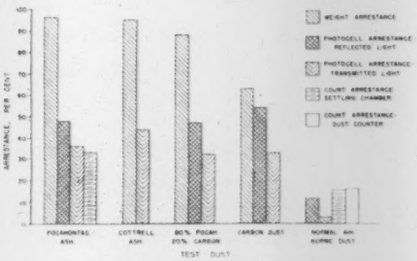


Fig. 7—Comparison of weight, particle count and discoloration arrestances for Filter *B* with various test dusts

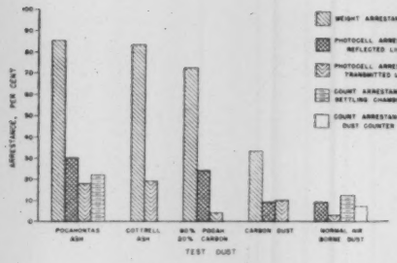


Fig. 8—Comparison of weight, particle count and discoloration arrestances for Filter *C* with various test dusts

any of the artificial dusts.

4. In several instances the discoloration arrestances for Pocahontas ash and for carbon dust were both higher than for the 80-20 mixture using these same dusts as components. The exact reason for this is unknown, but it may be caused by a change in the physical characteristics of the aggregate over those of either of its constituents.

Continuous Discoloration Filter Tests

In order to determine the effect of dust loading upon the arrestance of air filters tested by the reflected light discoloration method, and also to gain a direct comparison of the weight and reflected light arrestances, continuous tests were conducted on Filters *B*, *C*, and *D* with determinations made by the weight and discoloration methods. The 80-20-dust mixture was used as a test dust, the rate of feed was 20 g per hour, and the filter face air velocity 300 fpm. At the beginning of each test hour the discoloration arrestance was determined after which the dust plate was removed and re-weighed and the weight arrestance determined on the remaining dust. The discoloration arrestance determination consumed approximately 5 out of the 20 g of dust, and the weight arrestance was determined on the remaining portion. Filter *D* was tested only by the reflected light discoloration method as the weight arrestance was so high that determinations of the increase in weight of the dust crucible were difficult when based upon a dust feed of only 15 g weight.

The results of these tests shown in Figs. 10, 11 and 12 indicate in all cases a marked rise in reflected light discoloration arrestance with increased weight of dust fed. The arrestance of Filter *D* rose from 50 to 75 per cent during an increase of filter resistance of only 0.05 in. of water. Filter *C* rose in discoloration arrestance from 13 to 43 per cent during an increase in filter resistance of 0.15 in. of water, while during the same time the weight arrestance remained substantially constant. Filter *B* rose in discoloration arrestance from 46 to 55 per cent during a resistance rise of 0.12 in. of water, while the weight arrestance rose only 5 per cent. These tests indicate that, when continuous tests are made on air filters with the arrestances determined by the discoloration method, much greater variations can be expected than when the arrestances are determined by the weight method. Although none of these tests were conducted over any definite increase in pressure drop across the filter, they indicate that continuous tests can be used to determine the life and arrestance of air filters by the discoloration method. However, the determination of the dust holding capacity by such a test would not be possible.

Correlation of Filtering Theory with Test Results

It is apparent from these test results that the three methods of rating filters (weight, discoloration, and particle count) are not comparable and each method measures a somewhat different characteristic of the filter. The particle count method of rating air filters does not distinguish between large and small particles but gives equal emphasis to both. The emphasis given to different sizes of particles by the weight method is in direct relation to the cube of the diameter of the particle as long as the density remains constant. For the discoloration method there is probably no simple relationship between relative effect and size of particle, but it would appear that the projected surface area would be one of the dominating factors. Thus, in this case, the relative effect would be at least partially in relation to the square of the diameter of the particle. If these relationships are true, when tested by the weight method a 10 μ (micron) particle has 1,000 times as much effect on the ultimate rating as a 1 μ particle, and when tested by discoloration the relationship is

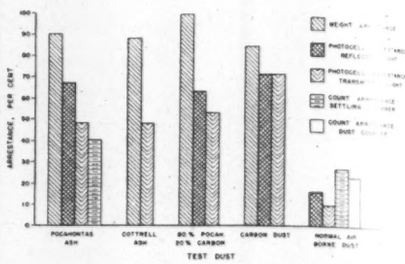


Fig. 9—Comparison of weight, particle count and discoloration arrestances for Filter *D* with various test dusts

100 to 1. When rated by the particle count method both the 10 and 1 μ particles have equal effect.

If air filters were capable of eliminating both large and small dust particles with equal ease there would be little difference between the ratings obtained by the different methods. However, that such is not the case is indicated by Fig. 13 which shows the relationship between size of dust particle and filtering arrestance for three different filters. These results were obtained by the weight method of testing, using a test dust consisting of Pocahontas ash, separated into different size fractions by means of a Federal Pneumatic Air Classifying Unit, the actual particle size being determined by microscopic examination. In these curves arrestance has been plotted against *diameter in microns of dust particle with average volume* since this statistical diameter is also the measure of the dust particle with average weight if the density remains constant. These curves indicate a definite dropping off in arrestance for the smaller sizes of particles for both Filters *B* and *C*. Filter *D*, which incorporated cotton fiber filtering media, showed no noticeable reduction in arrestance within the dust size fractions used

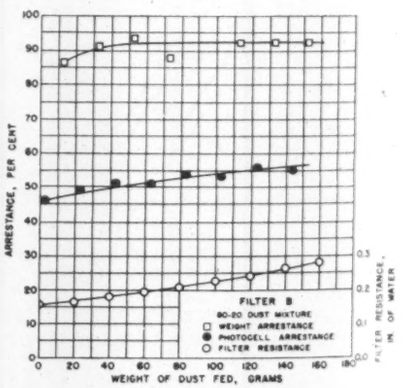


Fig. 10—Comparison of weight and discoloration performance curves for Filter *B*

in these tests, but very possibly there would have been a lowering of arrestance if it had been possible to extend the test down to ash particles of finer size.

Air-borne dusts are apparently constituted principally of particles of small size. We may therefore assume a hypothetical case in which a filter is 90 per cent efficient on particles of 10 μ diameter and 10 per cent efficient on particles of 1 μ diameter, and the test dust to which the filter is subjected consists of 99 per cent by number of 1 μ particles and 1 per cent of 10 μ particles. If the filtering arrestances are then calculated by the weight, particle count, and discoloration methods of test applying the assumptions previously discussed it is found that the count arrestance is 11 per cent, the discoloration arrestance 50 per cent, and the weight arrestance 83 per cent. This coincides in general magnitude with the actual test results previously reported with the exception that the discoloration arrestance calculated here is higher. Actually the discoloration arrestance will be dependent principally upon the projected area only when transmitted light and opaque dust particles are used. Under actual operating conditions such factors as the opacity of the dust particles in the case of transmitted light and the relative reflectivity of dust particles in relation to that of the filter paper in the case of reflected light will be equally as important as the projected areas.

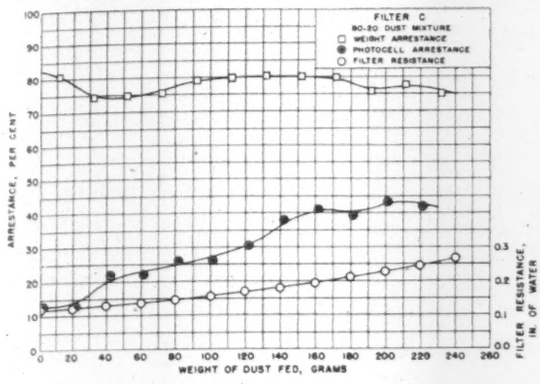


Fig. 11—Comparison of weight and discoloration performance curves for Filter *C*

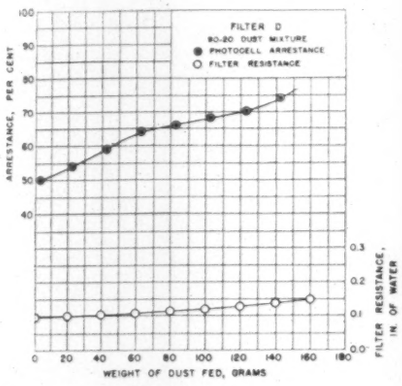


Fig. 12 — Discoloration performance curves for Filter *D*

In order to determine how high a transmitted light discoloration arrestance could be obtained when using filters based upon mechanical principles of operation, a special filter was constructed and tested. This filter consisted of a Filter *B* of stock construction operated in tandem with fourteen layers of oiled cheese cloth supported on a wood frame. When tested with 200-mesh Pocahontas ash the arrestance of this combination by the transmitted light discoloration test was 68 per cent. This same filter combination when tested by the weight method on the same test dust had an arrestance of approximately 94 per cent. When the 14 layers of cheese cloth were removed from the back of the filter and the weight and discoloration arrestances re-run, the weight arrestance was still 92 per cent, whereas the discoloration arrestance dropped to 36 per cent. Thus the addition of the cheese cloth screen in tandem operation with this filter raised the transmitted light discoloration arrestance 32 percentage units, while the weight arrestance remained substantially constant. This test clearly indicates the independence of the weight method and the dependence of the discoloration method upon the elimination of the small particles contained in the dust suspension.

The results of all tests indicated that filters based upon mechanical separation of the dust from the air removed the large dust particles much more easily than the small ones. In order to verify further this selective filtering action samples of normal air and of air discharged from filters were obtained in settling chambers and the dust allowed to settle onto glass slides for a period of 24 hours. These slides were then subjected to microscopic examination and the diameters of from 300 to 500 particles per sample recorded. From these data, assuming spherical particles, the average diameter, the diameter of the particle with the average surface area, and the diameter of the particle with the average volume were determined. These statistical diameters were calculated by use of the following Equations (8), (9) and (10):

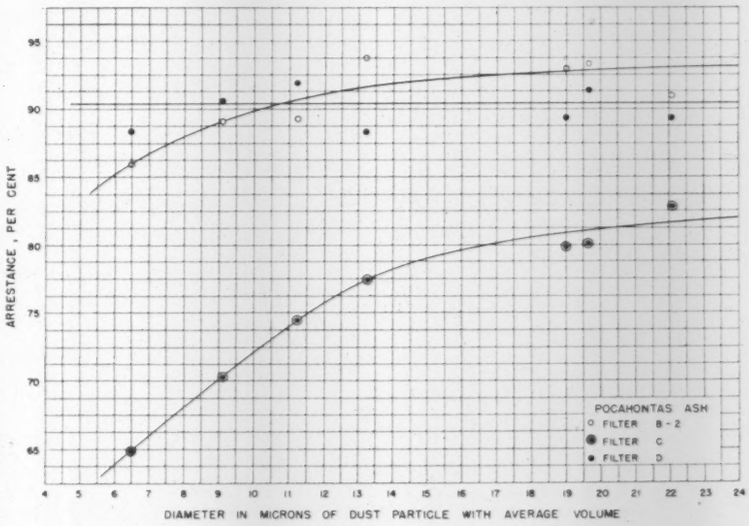


Fig. 13—Effect of dust particle size on weight arrestance for Filters *B*, *C* and *D*

$$\text{Average diameter} = \frac{\Sigma\,(FD)}{\Sigma F} \quad \ldots\ldots (8)$$

Diameter of particle with average surface

$$\text{area} = \left[\frac{\Sigma\,(FD)^2}{\Sigma F}\right]^{1/2} \quad \ldots\ldots (9)$$

Diameter of particle with average vol-

$$\text{ume} = \left[\frac{\Sigma\,(FD)^3}{\Sigma F}\right]^{1/3} \quad \ldots\ldots (10)$$

where,

F = dust particle group frequency.
D = average diameter of group limit.

The results of these tests are recorded in Table 2 for air discharged from Filters *B*, *C*, and *D*, and for two samples of unfiltered room air.

These results indicate a definite preferential filtering of the air for all three filters. The diameter of the particle with average volume was reduced from approximately 17 μ to 9.6 μ for Filter *D*, 10.9 μ for Filter *B*, and 11.0 μ for Filter *C*. There were corresponding reductions in the average diameters and in the average surface area diameters.

The particle count arrestances (Table 1) and the particle size distribution data (Table 2) may be used to calculate weight arrestances as a check on the actual weight arrestance test values. For example, the volume of particle with average volume upstream of Filter *B* is then 2716 cu microns and downstream is 676 cu microns. As the dust counter particle arrestance was 16 per cent the calculated weight arrestance is then,

$$\text{Arrestance} = 100\left[\frac{2716 - 676\ (1 - 0.16)}{2716}\right] = 79 \text{ per cent} \quad \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Table 3 shows a comparison of the calculated weight arrestances with actual test weight arrestance values. The actual test values recorded for weight arrestance were for the first hour of test using an 80-20 dust mixture. This initial arrestance was chosen because the dust size distribution data were also determined on unloaded filters. It should be noted that the calculated weight arrestances are all based upon data determined using normal suspensions of dust in room air and that the actual weight arrestance values were determined with an artificial dust mixture. However, previous tests[11] have shown that weight arrestances made on normal air-borne dust check quite closely with those for this artificial mixture.

The reasonably close check for all three filters of the calculated weight arrestance and the actual test weight arrestance values along with the data showing the reduction in size of the average particle upon passage through the filters verify the evidence previously presented as to the selective filtering of mechanical filters.

[11] Loc. Cit. Note 3.

Table 2—Comparison of Size of Dust Particles on Entering and Discharge Sides of Typical Air Filters

Source of Dust Sample	Average Diameter, Microns	Diameter of Particle with Average Surface Area, Microns	Diameter of Particle with Average Volume, Microns	Per Cent Particles by Number Smaller Than:		
				6μ Diameter	18μ Diameter	30μ Diameter
Laboratory Air	7.2	11.3	16.1	62.9	91.5	97.0
Laboratory Air	9.6	13.8	18.4	48.1	83.5	95.4
Air Downstream from Filter *B*	3.5	6.8	10.9	89.0	96.9	98.5
Air Downstream from Filter *C*	4.7	7.6	11.0	79.3	95.0	99.0
Air Downstream from Filter *D*	3.8	6.6	9.6	86.8	96.5	98.7

The following conclusions may be drawn from these investigations:

1. Tests conducted by the weight method using Pocahontas ash of different particle size fractions indicate a definite preferential filtering of the larger particles over the smaller ones.

2. Theoretically the emphasis given to different sizes of particles by the weight method varies as the cube of the diameter, whereas the particle count method gives equal emphasis to all sizes. The effect of particle size upon discoloration arrestance probably varies as the square of the diameter, although undoubtedly other factors are of equal importance in this case.

3. Tests made using 200-mesh Pocahontas ash on a stock filter with and without a series of fourteen oiled cheese cloth screens in tandem showed no appreciable differences in the weight arrestances, but a difference of 32 percentage units in the transmitted light arrestances. This indicates the independence of the weight test results and the dependence of the discoloration test results upon the small particles when the test dust is composed of both large and small particles.

4. Tests made to determine the effect on average particle size of dust suspensions subjected to air filtration showed a marked decrease in the average particle diameter, the diameter of the particle with average surface area and the diameter of the particle with average volume. These data, together with the particle count arrestances, were used to calculate weight arrestances. These calculated arrestances checked reasonably well with the actual weight arrestance test values.

Relative Merits of the Three Filter Test Methods

From the standpoint of a practical test to be used in the rating of air filters each of the three methods discussed has certain inherent advantages and disadvantages. The more important of these may be summarized as follows:

Weight Method

The weight or crucible method of rating air filters has the advantages of high accuracy (estimated that results can be reproduced approximately within ± 1 per cent) and readily allows determinations to be made of filter life and dust holding capacity as well as arrestance. Furthermore, the performance characteristics can be determined when the filter is subjected to lint as well as dust. However, the weight method measures the ability of the filter to remove principally the large dust particles from the air. The smaller particles, which play a prominent part in arrestance determinations based on particle count and discoloration, have little effect on weight arrestances.

Particle Count Method

This filter test method in its present state of perfection requires too long a time to make a determination which can be considered statistically reliable. However, there is consid-

Table 3—Comparison of Calculated and Test Weight Arrestances

Filter	Vol. Avg Particle Entering Filter, Cu Microns	Vol. Avg Particle Leaving Filter, Cu Microns	Actual Test Arrestance, Per Cent		Calculated Weight Arrestance, Per Cent
			Count	Weight	
B	2716	676	16	88	79
C	2716	684	7	72	76
D	2716	505	22	94	86

erable evidence that arrestances based on particle count are better measures of the degree to which dust dangerous to human health is eliminated. Such an arrestance determination is not necessarily a measure of the elimination of nuisance dust, and the type and concentrations of dust normally experienced in other than industrial structures are probably not harmful. Therefore, it would appear that the most practical application of this test method would be its development to determine the degree to which dangerous dust concentrations are actually reduced in filtering installations.

Discoloration Method

Both the transmitted and reflected light discoloration test methods have a reasonably good accuracy (estimated at ± 3 per cent). Although these test methods have not in the past been conducted in conjunction with determinations of filter life, there is no reason why this performance characteristic cannot be determined as indicated earlier. However, it would probably be impossible to devise a lint test which could be used in conjunction with this method of determining arrestance.

This method is advanced as a means of determining the arrestance based on the reduction of discoloration or soiling power of the air-dust mixture and therefore probably best measures this property when reflected instead of transmitted light is used. Furthermore, when reflected light arrestance determinations are made it is not necessary to match the unused blank filter papers as is the case with the transmitted light determinations, and the elimination of this procedure reduces appreciably the testing time. The amount of light reflected from the surface of the blank filter papers is practically constant, whereas the amount of light transmitted through these same papers usually varies considerably. Actually, both the reflected and transmitted light methods measure the reduction and discoloration only in relation to the test dust being used, and the arrestances vary greatly for the same filters with different test dusts.

For other than applications designed to eliminate dusts dangerous to health it would appear that the best filter arrestance or efficiency measure would be that which most accurately measured the percentage of nuisance dust eliminated. The question remains, however, as to whether the best measure of nuisance dust is the relative ability of the dust to discolor white surfaces or the weight of the large dust particles which are visible to the human eye. The photo-electric cell method is probably the best measure of the reduction in discoloration, while the crucible or weight method is the best measure of the reduction of the larger visible dust particles.

Prof. F. B. Rowley
Minneapolis, Minn.

PROFESSOR ROWLEY HEADS DEPARTMENT OF MECHANICAL ENGINEERING

The University of Minnesota recently announced the appointment of Frank B. Rowley as Head of the Department of Mechanical Engineering and Director of the Engineering Experiment Station. Professor Rowley has been a member of the University faculty since 1907 when he became an instructor in engineering.

Joining the Society in 1918 Professor Rowley has served as its President in 1932, as a member of the Council from 1927 to 1933, as Chairman of the Committee on Research in 1929, Chairman of the Publication Committee in 1927, and also as President of the Minnesota Chapter in 1922. Since 1919 he has served on innumerable technical committees and was instrumental in producing the Society's Standards on Testing of Air Cleaning Devices and the Code for Determining Heat Transmission through Building Walls. He is the author of many papers in the Society's TRANSACTIONS and has contributed many scientific articles to engineering publications.

DEVELOPMENT OF MOTORS TRACED AT PITTSBURGH

February 10, 1941. Pres. E. C. Smyers called the February meeting to order in the Marine Room of the Hotel Roosevelt, and the minutes of the January meeting were read and approved as read.

Various reports, including the treasurer's and membership committee's, were accepted, and a resolution was read by the secretary to amend Section 2 of the By-Laws of the Pittsburgh Chapter as follows:

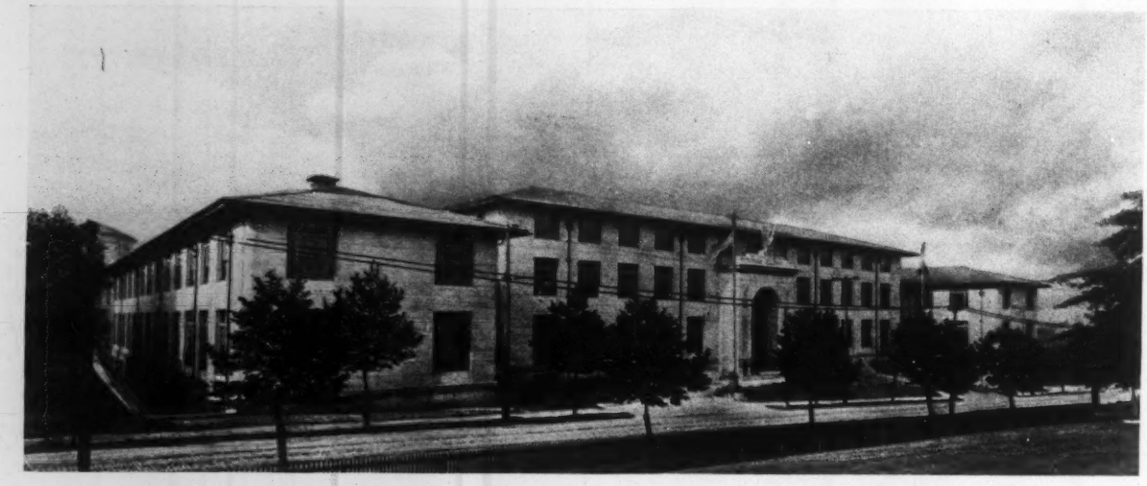
One regular meeting shall be held during each of the following months: January, February, March, April, May, September, October, November and December. The regular date for these meetings shall be the second Monday of the month; except that the date may be changed by action of the Board of Governors whenever it deems such change to be for the best interests of the chapter. The May meeting is designated as the annual meeting, at which the election of officers and similar yearly business will be conducted.

It was further resolved that Section 5 of the By-Laws of the Pittsburgh Chapter be amended as follows:

The President shall appoint a nominating committee of three members at least sixty days before the annual meeting. Said committee shall select a list of candidates for the various offices, which list shall be presented to the chapter at the April meeting. Nominations may also be made from the floor at either the April or May meeting.

It was further resolved that these amendments shall take effect at once, and that the next annual meeting of the Pittsburgh Chapter shall be held in May, 1941, and the motions were moved by A. F. Nass and seconded by R. J. J. Tennant.

The guest speaker was R. W. Monroe, application engineer for Westinghouse Electric and Mfg. Co., who spoke on electric motors and control. Mr. Monroe traced briefly the development of motors and then discussed the characteristics of the various types with particular emphasis on their application to heating and ventilating equipment, and illustrated his talk with slides. A large number of questions indicated the great interest in the subject. The meeting, which was attended by 35 members and guests, adjourned at 10:15 p.m.



Pittsburgh Experiment Station of the U. S. Bureau of Mines where the Research Laboratory of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS is located

Heat Gain Through Western Windows With and Without Shading

F. C. Houghten* and David Shore**
Pittsburgh, Pa.

HEAT gain through windows as a result of solar radiation is recognized as an important factor in summer cooling and air conditioning. The magnitude of this cooling load for unshaded and shaded windows, with different sun-arresting appurtenances, was reported[1] by the Laboratory for southern windows in 1934. The increasing interest in heat gain through various types of windows, including glass block, led to the building of two new cubicles or calorimeters on the roof of the U. S. Bureau of Mines Warehouse Building, Pittsburgh, in 1939. This new equipment was built on a turntable so that it could be made to face any horizontal direction, making it possible to study east and west windows.

The Technical Advisory Committee on Air Conditioning Requirements of Glass[2] provided a budget for the present study, the plans for which included the window and window shading arrangements listed in Table 1. The weather conditions during the past summer greatly limited the number of satisfactory tests which could be made. Nevertheless it is believed that the findings are of sufficient practical value to warrant their publication in this preliminary report pending a continuation of the investigation next year.

The two cubicles made it possible to simultaneously test and compare two window arrangements. The collection and analyses of the data were so arranged as to give the hourly total heat gain rate for the window, that gained as a result of radiation, and that gained by air to air transmission, as well as the percentage which the radiation gain was of the incident solar radiation on the outside of the glass. The comparative tests of two windows on single days permit a very close comparison, while the percentage which the solar radiation gain on any day was of the incident radiation allows a less accurate, though satisfactory, comparison of any of the arrangements tested.

The shading devices included a typical green canvas awning extending 4½ in. on each side and to within 2 ft x 7 in. of the bottom of the window. At its lowest point it extended out horizontally a distance of 3 ft and was ventilated at the edges to allow the escape of trapped warm air. A typical dark green, cloth roller shade, 4 ft x 3 in. wide and opaque to any visible light radiation, was placed on the window frame so that the plane of the drawn shade was 1½ in. from the glass. The inside venetian blinds, completely covering the window opening, had bright aluminum curved slats, 2 in. in width, spaced 1⅝ in. apart, and so placed that their main axes formed an angle of 45 deg with the horizontal. The outside venetian blind was of cream painted metal slats and adjustable both as regards the angle of the slats and the slope of the blind away from the window; that is, its bottom could be extended away from the window as an awning. The shading screen was similar to a venetian blind, having very small slats, and designed to serve both the purpose of a fly screen and sun arrester. It

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**Research Engineer, ASHVE Research Laboratory. JUNIOR MEMBER of ASHVE.

[1] Studies of Solar Radiation Through Bare and Shaded Windows, by F. C. Houghten, Carl Gutberlet and J. L. Blackshaw. (ASHVE TRANSACTIONS, Vol. 40, 1934, p. 101).

[2] ASHVE Technical Advisory Committee on Air Conditioning Requirements of Glass: M. L. Carr, *Chairman*; C. M. Ashley, L. T. Avery, F. L. Bishop, W. A. Danielson, H. C. Dickinson, J. D. Edwards, J. E. Frazier, S. O. Hall, E. H. Hobbie, C. L. Kribs, Jr., Axel Marin, R. A. Miller, F. W. Parkinson, J. H. Plummer, W. C. Randall, L. T. Sherwood, J. T. Staples, G. B. Watkins, F. C. Weinert.

Presented at the 47th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Kansas City, Mo., January, 1941.

Table 1—Window Arrangements Studied

Number of Test	Date	Direction Faced	Room Number	Actual Glass Area Sq Ft	Condition Tested
3	7/25	West	1[a]	24	Unshaded single light window
		West	2[b]	24	Unshaded single light window
5	7/31	West	1	24	Unshaded single light window
		West	2	24	Completely shaded single light window
7	8/2	West	1	24	Window shaded on outside with awning
		West	2	24	Window shaded on outside with venetian blind
13	8/11	South	1	21.8	Unshaded twelve light wood sash window
		South	2	24	Unshaded one light wood sash window
17	8/17	West	1	24	Window shaded on outside by "shading screen" and on the inside by venetian blind
		West	2	24	Window shaded on outside by "shading screen"
37	9/18	West	1	24	Window shaded with venetian blind on the inside
		West	2	24	Window shaded with half-drawn roller shade inside
39	9/20	West	1	24	Unshaded single light window of heat absorbing glass
		West	2	24	Unshaded single light window of plain 3/16 in. sheet glass
47	9/28	West	1	21.8	Unshaded twelve light wood sash window
		West	2	21.1	Unshaded twelve light steel sash window
50	10/4	West	1	24	Double glazed window—single light both outside and inside plain 3/16 in. sheet glass
		West	2	24	Double glazed window—single light, outside glass heat absorbing, inside plain 3/16 in. sheet glass

[a]Room 1—South side with window facing west.
[b]Room 2—North side with window facing west

had dark colored metal slats 0.050 in. wide, spaced 0.063 in. apart, and placed at an angle of 17 deg with the horizontal.

A photograph of the cubicles with a venetian blind on a western exposed, plain, single light, double-glazed window and a single light, double-glazed window shaded by an awning with heat absorbing glass on the outside and plain glass on the inside is shown in Fig. 1. A plan of the cubicles showing the arrangement of the test equipment is given in Fig. 2.

Test Procedure

The test procedure, the data collected, and the analyses of the same in order to arrive at the heat gain through the glass by radiation and by transmittance were in most instances the same as in last year's study of heat gain through glass blocks,[3] the report of which cites these arrangements in greater detail than will be reported here. The cubicles were cooled by ice melting unit coolers. Ice meltage collected at 20 min intervals gave a measure of the total heat extracted in order to maintain the desired temperature level in the cubicle, usually 78 F. In all of the tests calibrated heat meters made it possible to determine the heat gain through the ceilings, floors, and walls other than the glass. Infiltration tests gave the magnitude of the heat gain by this avenue. The difference between the heat extracted and that gained through avenues other than the glass gave the total heat gain through the window. Calculations using the inside and outside air temperatures at a distance of 6 in. from the glass and the transmittance coefficient gave the heat gain through the windows resulting from the higher air temperature outside.

By difference the heat gain through the glass, resulting from radiation impinging on the outside, was determined. While it is recognized that this method offered a limitation in accuracy because of the fact that errors due to the calculations of heat gain by transmission and those resulting from the measurement of total heat gain through the window were thereby combined in the radiation gain, this method was nevertheless used because it offered the only possibility of determining the total effect which radiation had on heat gain to the room. If radiation had been measured by a pyrheliometer on the inside of the room it naturally would not have included the heat gain resulting from radiation but entering by conduction through the inside surface after being absorbed by the glass. In no case was the resulting heat gain from the inside-outside air temperature difference large, and, therefore, errors in the radiation values given, resulting from the difference, should not be significant.

It should be noted that not all of the heat gain charged to radiation necessarily passed through the inside surface of the glass as radiation, for some of the heat resulting from absorption of radiation in the glass itself naturally entered the room by conduction through the inside surface of the glass. This gain, however, all resulted directly or indirectly from the radiation impinging against the outside.

An Eppley pyrheliometer gave the total solar and sky radiation impinging against the plane of the window. Thermocouples gave the outside air temperature 6 in. away from the glass, the outside-inside glass surface temperatures, and the inside air temperature. Air velocity was observed by a cup anemometer whose rotations were indicated and read from a mechanical counter at one-half hour intervals.

In conducting a test, the coolers were charged with ice early in the

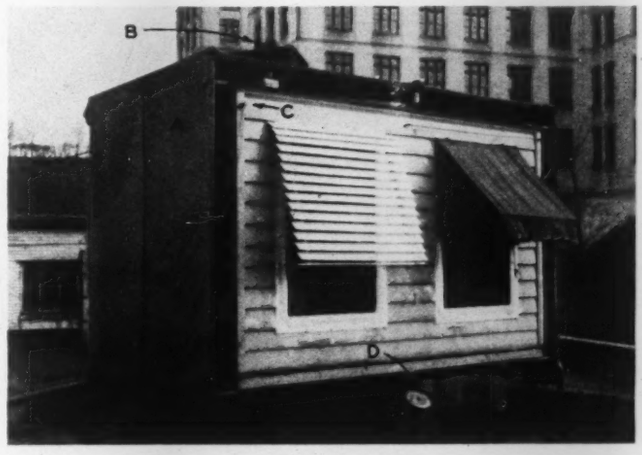


Fig. 1—Test house equipped with an outside venetian blind and an awning

A—Canvas shading screen
B—Cup anemometer
C—Pyrheliometer giving sun intensity on south wall
D—Pyrheliometer giving sun intensity perpendicular to rays

[3] Heat Gain Through Glass Blocks by Solar Radiation and Transmittance, by F. C. Houghten, David Shore, H. T. Olson, and Burt Gunst. (ASHVE Journal Section, *Heating, Piping and Air Conditioning*, April, 1940, p. 264).

morning and the rooms were closed. The desired inside temperature was maintained by manually adjusting the ice cooling rate to a value a little greater than that required and then adding a small amount of thermostatically controlled electrical heat. Constant conditions were maintained for a sufficient length of time before the collection of heat gain data to insure uniform temperature conditions. In all tests, whether for a southern or a western exposure, the data were collected from early morning, thus obtaining a measure of the effect of sky radiation until the sun began to strike the glass itself. These tests were continued for a time after sundown until the heat ceased or became negligible.

Test Results

The results of a single test on August 17 on one western exposed window equipped with *shading screen* are given in Table 2. Similar results of the one most satisfactory day for each of the thirteen conditions listed in Table 1 are plotted in Figs. 3 to 9, giving the actual solar radiation intensity impinging against the outside of the window in Btu per square foot per hour, the total heat gain charged to each square foot of the glass, the calculated air to air transmission through the glass, and the heat gain through the inside surface of the glass resulting from radiation impinging against the outside. In some cases it was found desirable to omit either the total heat gain or the transmission gain curves in order to avoid confusion. The fact that the radiant gain is equal to the total gain by radiation and transmission, less the transmission gain, makes it possible to determine the magnitude of one in terms of the other two.

Table 2—Test Data August 17 West Window with Outside Shading Screen. Plain 3/16 in. Sheet Glass and Wood Sash

Sun Time	Solar Intensity on Window Btu/Sq Ft/Hr		Outside Air Temp F	Inside Glass Temp. F	Heat Gain Through Glass						
	Observed	Design Aug. 1			Observed Rad. and Transmission	Calculated Air to Air Transmission	Radiation by Difference	Radiation in Per Cent Solar Intensity	Design		
									Radiation Aug. 1	Transmission 95 Deg-Day	Radiation and Trans. Aug. 1
9–10	21.7	22	78.8	82.0	2.1	0.8	1.3	6.0	1.3	3.0	4.3
10–11	26.7	24	80.3	84.0	4.5	2.3	2.2	8.2	2.0	6.2	8.2
11–12	35.5	25	83.1	86.0	9.0	5.1	3.9	11.0	2.7	9.8	12.5
12–1	60.4	60	85.2	88.0	14.6	7.2	7.4	12.2	7.3	13.0	20.3
1–2	78.3	123	85.4	87.6	19.2	7.4	11.8	15.0	18.5	15.5	34.0
2–3	84.3	180	84.1	88.3	21.4	6.1	15.3	18.2	32.8	18.0	50.8
3–4	114.2	206	83.5	90.8	32.4	5.5	26.9	23.5	48.4	18.0	66.4
4–5	157.2	186	83.7	90.5	55.3	5.7	49.6	31.5	58.6	17.5	76.1
5–6	91.1	120	82.6	86.0	44.0	4.6	39.4	43.3	52.0	15.0	67.0
6–7	9.1	40	80.3	80.4	8.6	2.3	6.3	69.2	27.7	12.2	39.9
7–8	0	1.5	74.7	76.8	—3.3	—3.3	0	0	0	9.5	9.5

For comparison the design solar radiation intensity which would impinge against the outside of the window and the resulting radiation gain through the window based on the percentage relationship of actual radiation against the outside of the window and the radiation gain through the glass are given. In the top of the figures are also given the outside glass surface temperature, the design outside air temperature curve for a 95 F day, and in most cases the inside air temperature. The percentages which the radiation gains were of the total radiation intensities impinging against the outside of the windows are also given.

The testing program was started early in July and continued until completed on October 4. Tests on a given set-up were started every morning which gave promise of satisfactory weather conditions and were continued throughout the day unless the weather became unsatisfactory. This program was continued on each window until at least one test run of a full day in length was obtained. The very unsatisfactory weather with the small percentage of clear, sunny days accounts for the extended length of the program and for the acceptance of certain tests on days when the solar radiation was not very near design conditions.

Discussion of Results

Considerable importance is attached to the design solar radiation and the design radiation and transmission gain through the windows. The term *design* is used in accordance with its usage by heating, ventilating, and air conditioning engineers in estimating values required in design and is construed as the outside solar radiation intensity on a summer day for which an engineer would design a cooling load. It naturally should not include the most severe day affecting the cooling capacity of the plant ever recorded, for this would require an excessively large cooling system; but on the other hand it should be high enough so that a cooling plant calculated to have sufficient capacity for this assumed condition would adequately take care of all but a very few of the most severe days. Similarly, the term *design radiation* implies the radiation which would come into an occupied space on a day when the solar radiation intensity was that accepted for design purposes; and *design transmission gain* is the heat gain by transmission, unaffected by radiation, on a day when the inside temperature was at the point required for comfort on a design temperature day. It will be observed that, while the highest outside air temperature in

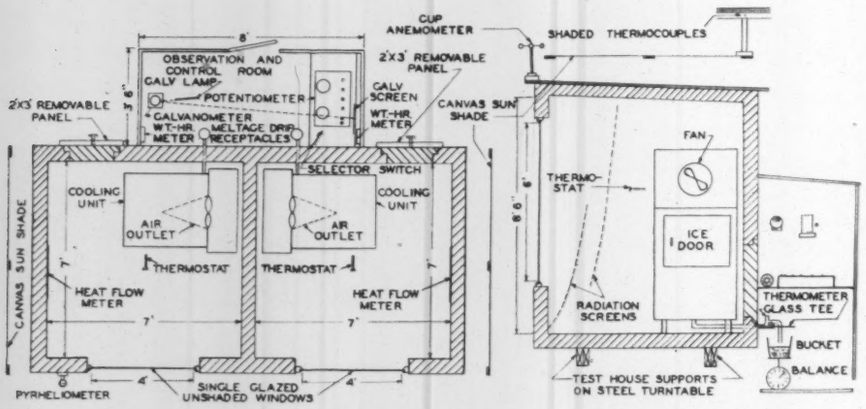


Fig. 2—Test set-up for determining solar radiation through windows

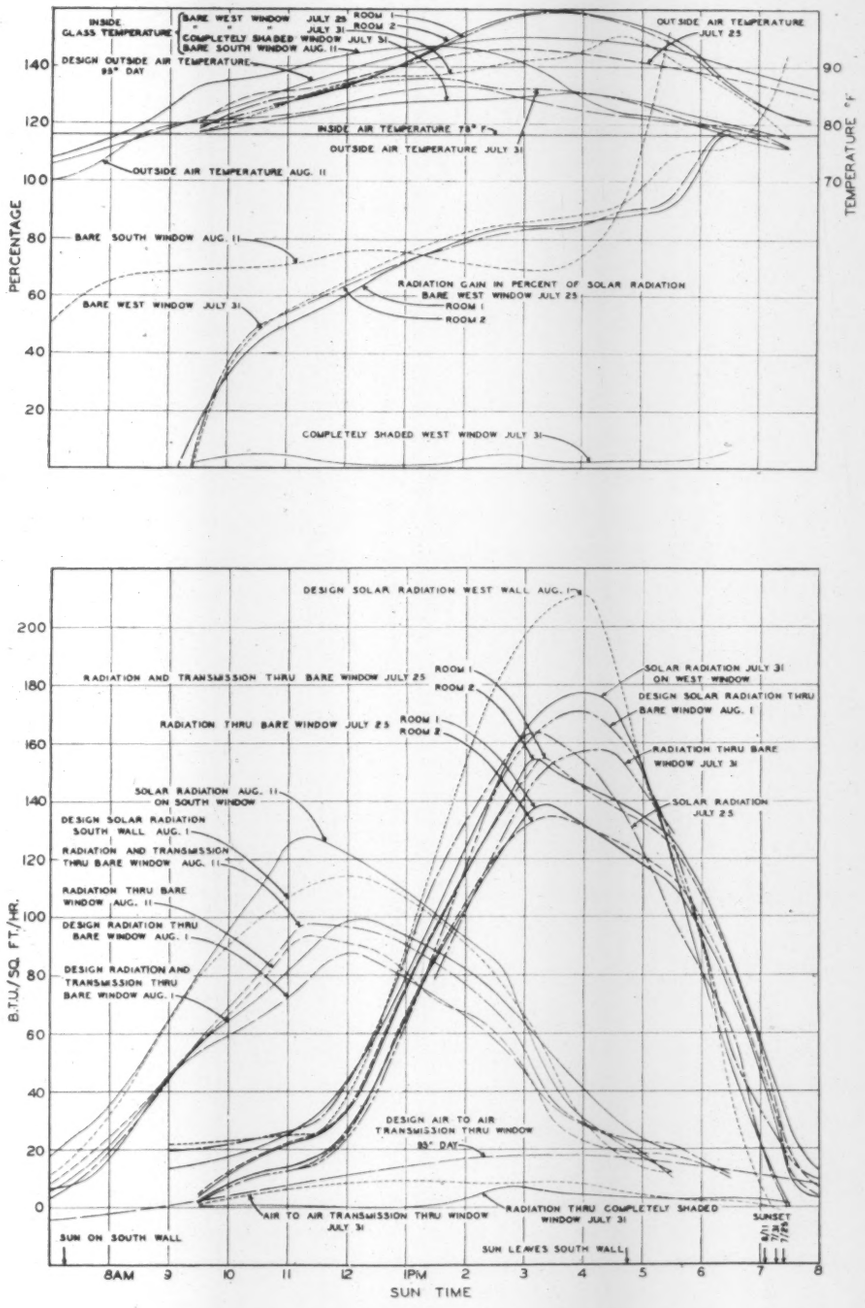

INSIDE GLASS TEMPERATURE
BARE WEST WINDOW JULY 25 ROOM 1
JULY 31 ROOM 2
COMPLETELY SHADED WINDOW JULY 31
BARE SOUTH WINDOW AUG. 11
DESIGN OUTSIDE AIR TEMPERATURE 95° DAY
OUTSIDE AIR TEMPERATURE JULY 25
INSIDE AIR TEMPERATURE 78° F.
OUTSIDE AIR TEMPERATURE JULY 31
OUTSIDE AIR TEMPERATURE AUG. 11
BARE SOUTH WINDOW AUG. 11
RADIATION GAIN IN PERCENT OF SOLAR RADIATION
BARE WEST WINDOW JULY 25
ROOM 1
ROOM 2
BARE WEST WINDOW JULY 31
COMPLETELY SHADED WEST WINDOW JULY 31
PERCENTAGE
TEMPERATURE °F.
DESIGN SOLAR RADIATION WEST WALL AUG. 1
RADIATION AND TRANSMISSION THRU BARE WINDOW JULY 25
ROOM 1
ROOM 2
SOLAR RADIATION JULY 31 ON WEST WINDOW
DESIGN SOLAR RADIATION THRU BARE WINDOW AUG. 1
RADIATION THRU BARE WINDOW JULY 25
RADIATION THRU BARE WINDOW JULY 31
SOLAR RADIATION AUG. 11 ON SOUTH WINDOW
SOLAR RADIATION JULY 25
DESIGN SOLAR RADIATION SOUTH WALL AUG. 1
RADIATION AND TRANSMISSION THRU BARE WINDOW AUG. 11
RADIATION THRU BARE WINDOW AUG. 11
DESIGN RADIATION THRU BARE WINDOW AUG. 1
DESIGN RADIATION AND TRANSMISSION THRU BARE WINDOW AUG. 1
DESIGN AIR TO AIR TRANSMISSION THRU WINDOW 95° DAY
AIR TO AIR TRANSMISSION THRU WINDOW JULY 31
RADIATION THRU COMPLETELY SHADED WINDOW JULY 31
SUNSET
SUN ON SOUTH WALL
SUN LEAVES SOUTH WALL
B.T.U./SQ. FT./HR.
8AM
IPM
SUN TIME

Fig. 3—Solar radiation heat gain relationships

Two, west, unshaded, single-light, single-glazed windows—July 25
One, west, unshaded, single-light, single-glazed window—July 31
One, west, completely shaded, single-light, single-glazed window—July 31
One, south, unshaded, single-light, single-glazed window—August 11

the shade ever recorded for Pittsburgh was about 104 F, cooling design in Pittsburgh is usually based upon a day when the maximum reaches 95 F.

Design solar radiation intensity for August 1 was obtained by an analysis of weather bureau data in an earlier Laboratory report[4] and represents a fairly high solar radiation intensity such as may be expected to occur on two or three days during any summer. Design radiation gain is the gain which would have occurred on any given day for any window condition if the radiation intensity had been equal to the design solar radiation on August 1. This was obtained by applying the same percentage to the design solar radiation as the observed radiation gain through the window was of the actual solar radiation for the given time of test. Design air to air transmission through the glass is based upon the temperature maintained indoors and the outside air temperature cycle expected to occur on a day when the maximum air temperature reached 95 F. This transmission gain is applied to the design curves for August 1, but obviously the same transmission gain would occur on any 95 F day.

The preliminary tests of the two

[4] Loc. Cit. Note 3.

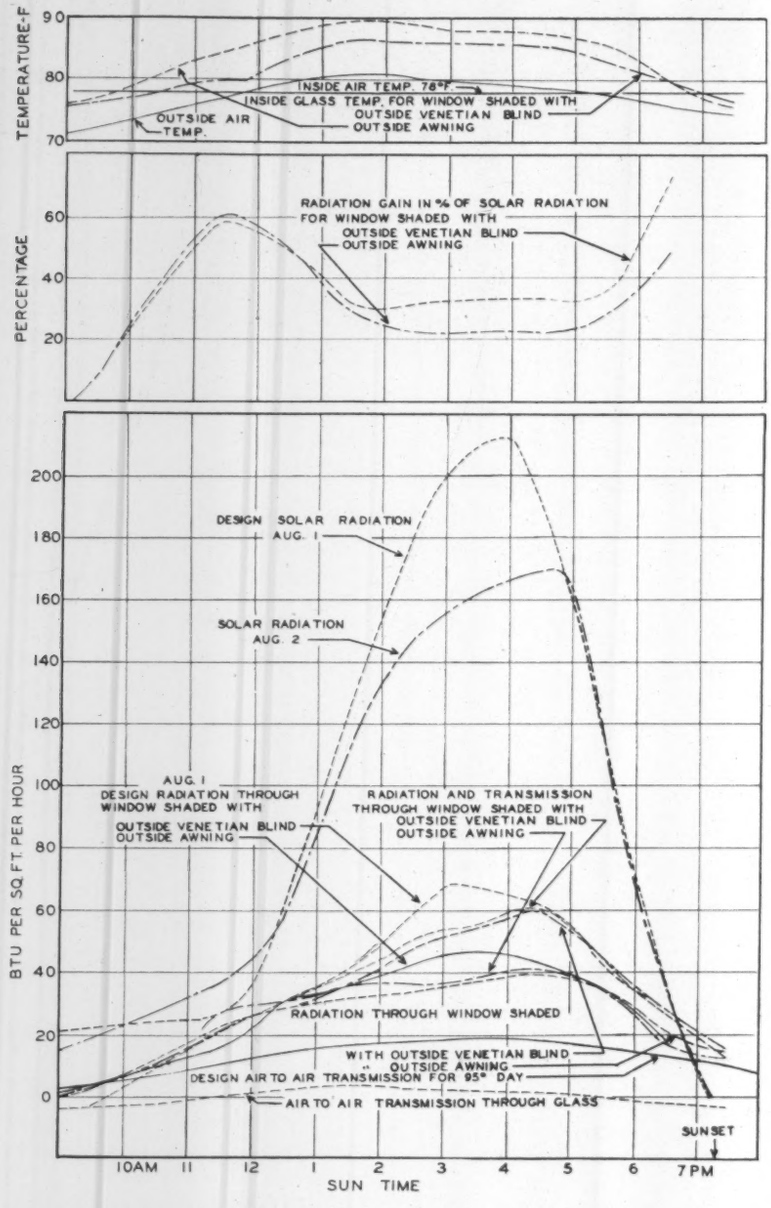


Fig. 4—Solar radiation heat gain relationships for west exposed windows (one shaded with an outside awning, and one shaded with an outside venetian blind)

identical, unshaded windows in the two cubicles on July 25 were for the purpose of checking the similarity of results from the two cubicles. It will be noted from the curves in Fig. 3 that the comparison is very satisfactory. The comparison of the curves in this figure for an unshaded, west window on July 25 and for an unshaded, south window on August 11, serves to show the relation between the magnitude and the time of maximum heat gain through the western and southern exposed windows. This relation seems to verify the claims of designing and operating engineers that worse conditions are frequently had for a western than for a southern window.

The characteristics of the curves for the percentages which the radiant gains were of the total impinging radiation intensities against the outside of the window are of interest. The high values of the percentage rates, which occasionally became as high as 100 per cent, are accounted for by two facts. *First,* the accumulation of heat within the glass due to the absorption of radiation and the resulting rise in temperature is finally given up, partly to the inside, at a time when the solar radiation reached a low value or had ceased entirely. *Second,* the fact that the intensity of the solar radiation impinging against the outside of the glass became low due to the small angle of impingement, or low solar intensity, when a relatively small and frequently unimportant heat gain became a high percentage. It is obvious that for such conditions the accuracy of the percentage curves is low. However, on these occasions the total heat gain is low and therefore the percentage is not important.

By shading the window *complete shading effect* was had, so as to entirely eliminate solar radiation impingement thereon and was obtained by arranging two thicknesses

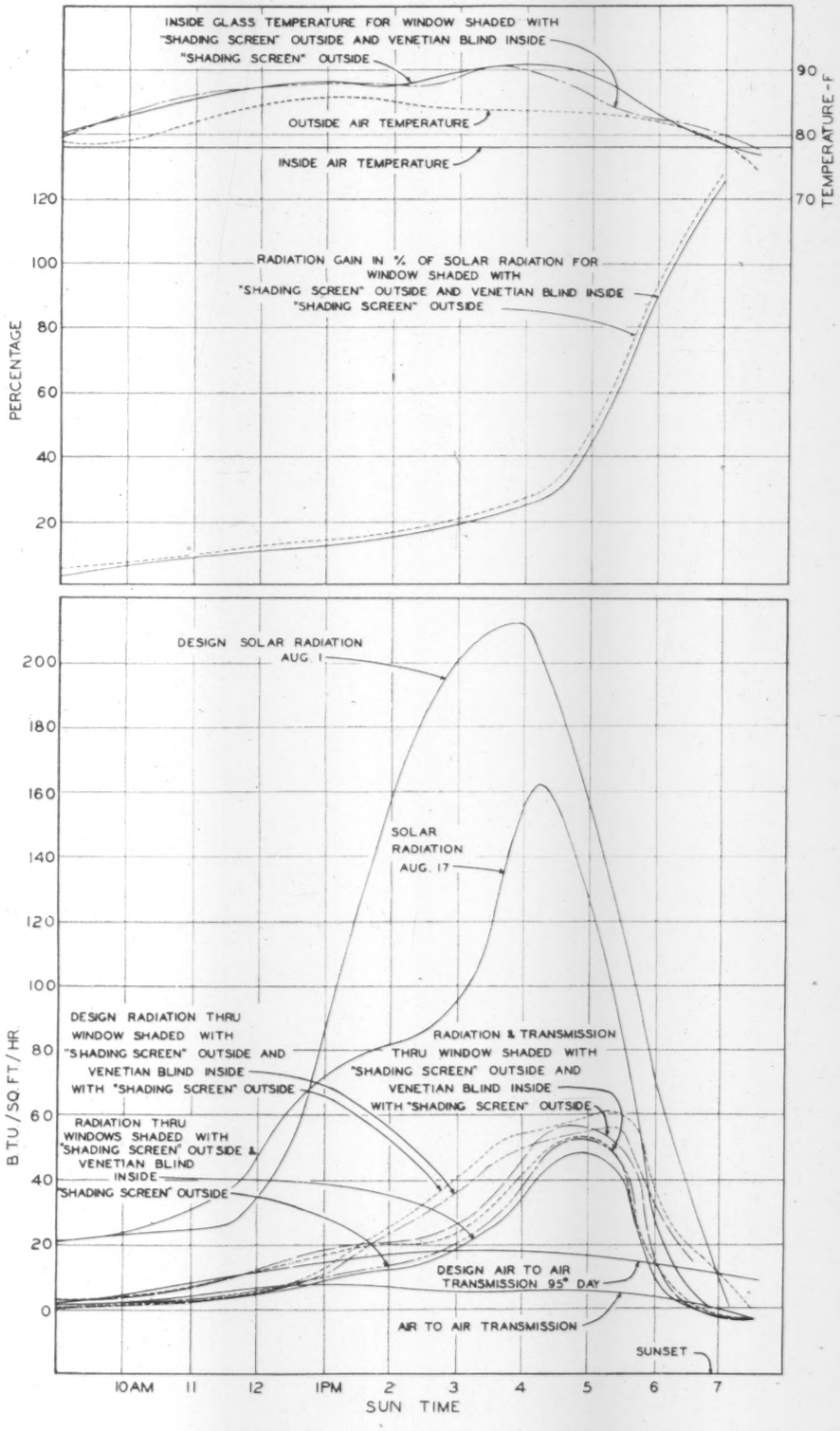


Fig. 5—Solar radiation heat gain relationships for west exposed windows (one shaded with *shading screen* on outside and a venetian blind on inside; one with *shading screen* on outside)

of canvas, sloping outward and downward before the window, so that the one nearest the window made an angle of approximately 10 deg with the vertical and the one farthest away twice this amount. It will be noted in Fig. 3 that the heat gain charged to radiation through the completely shaded window was negligible. The results for the unshaded and completely shaded windows serve to give two reference points for comparison with the other commercially shaded windows. These curves show that the unshaded window admitted a little under 90 per cent of the radiation impinging against the outside when the solar radiation was a maximum, while the completely shaded window admitted only 2 per cent.

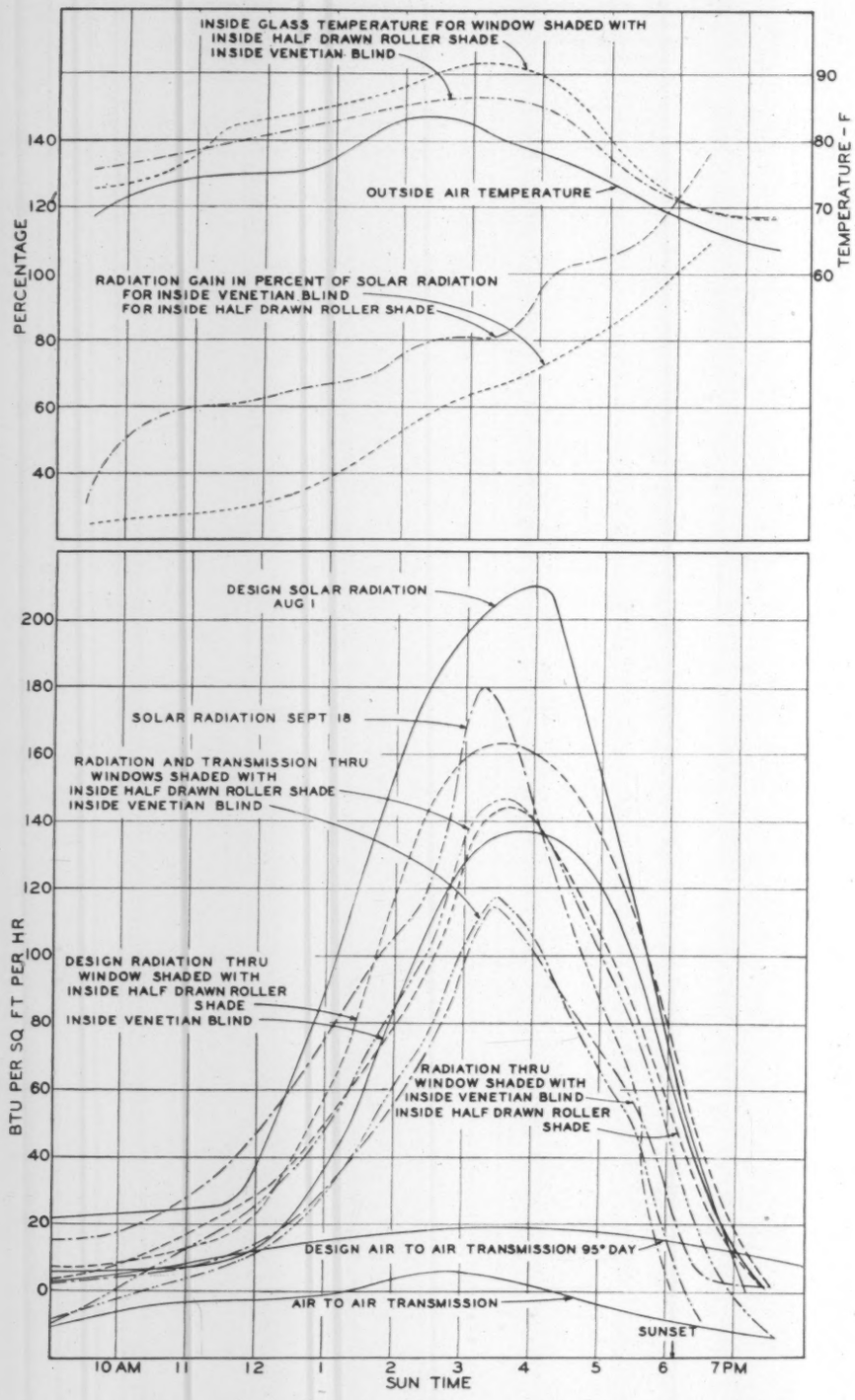


Fig. 6—Solar radiation heat gain relationships with west exposed windows (one shaded with venetian blind on the inside; the other shaded with a half drawn roller shade on inside)

The radiation gains through the *shading screen* with inside venetian blind on August 17, show increased gains in the afternoon, while the curve indicates that the sun did not shine through between the slats until about 4:20 p. m. Computation shows that this change should have occurred at about 3:40 p. m., indicating a 40 min lag.

Design data for heat gain through the different windows by radiation as plotted in the figures are given in Table 3. The first and last columns give the design solar radiation impinging on western exposed and southern exposed windows, respectively, for August 1. The design heat gain charged to radiation is expressed both in percentage of the design solar radiation intensity on the outside of the window, and in Btu per square foot per hour for each of the windows studied. These values are not always based upon the single tests plotted in Figs. 3 to 9 but represent rather the average of these tests and others. Hence, while these values will not always agree exactly with the curves, they

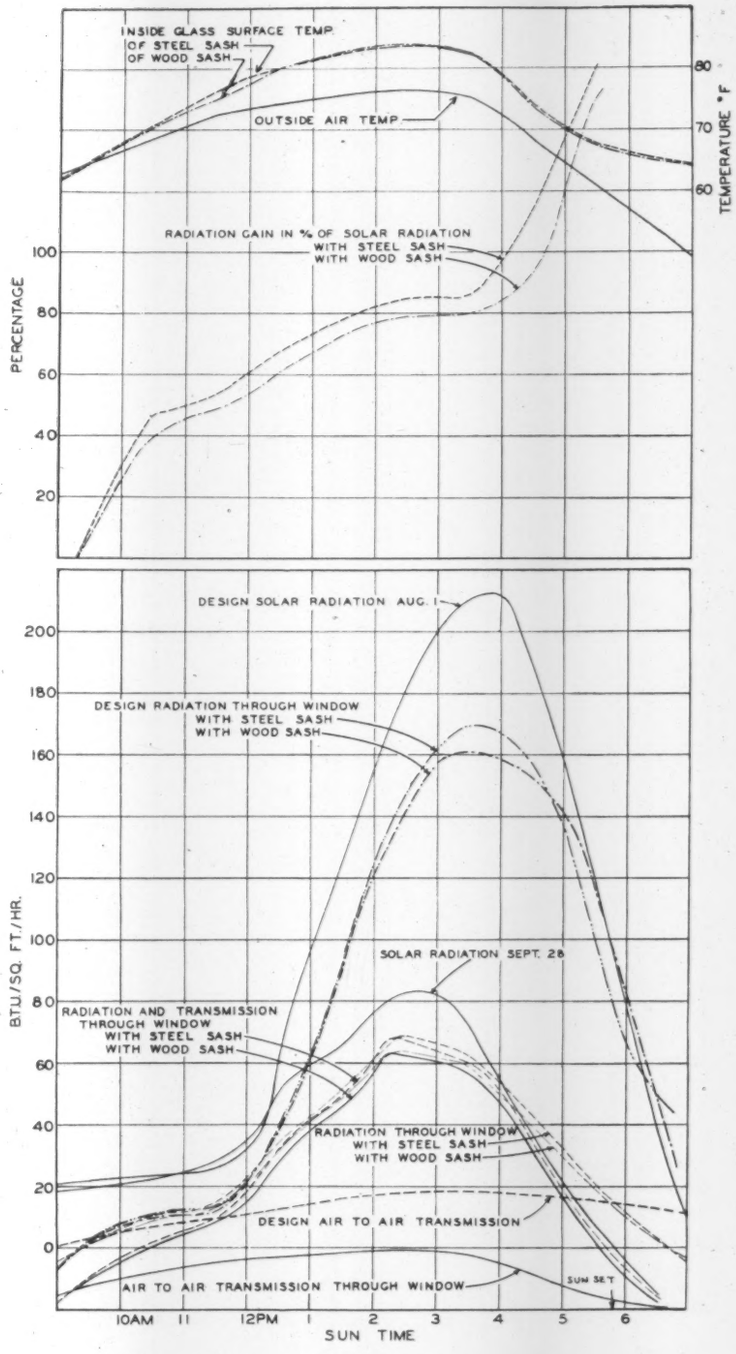


Fig. 7—Solar radiation heat gain relationships for west exposed windows, unshaded (one a 12-light, wood sash, and the other a 12-light, steel sash window)

are given as representing more nearly the true averages of what might be expected.

The total heat gain and that charged to radiation for the metal and wood sash windows on September 28, Fig. 7 and Table 3, shows slightly higher values for the metal sash. These values were based upon the superficial glass area, including the area of the muntin bars. Since the muntin bar area on the metal frame window was somewhat less than that for the wood frame, this penalized the metal window. When corrected for this difference the radiation heat gain indicated as 64.0 and 69.0 Btu per square foot per hour for the wood and metal sash at 2:30 p. m. in Fig. 7 become substantially the same when based upon the net free glass area.

The design air to air transmission for a 95 F day is given in the table for a single-glazed window. These values may be added to the design heat gain due to radiation to give the total heat gain through any single-glazed window. If the total heat gain through double-glazed windows is desired, it may be obtained by adding the design gain charged to radiation and the design

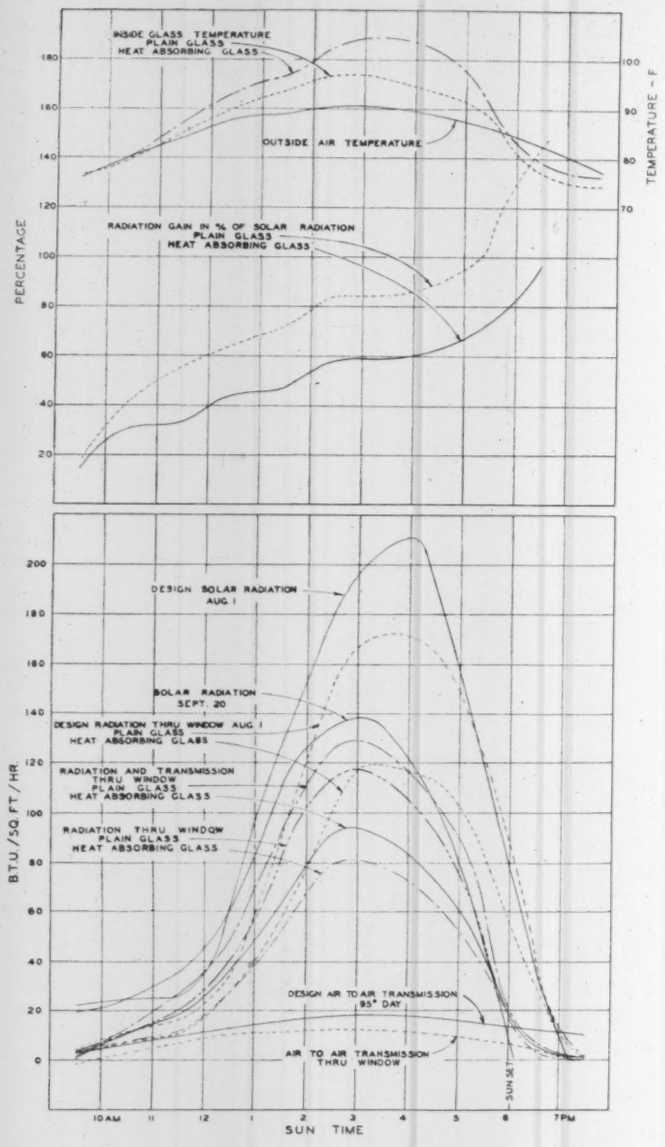


Fig. 8—Solar radiation heat gain relationships for west, unshaded, single-light, single-glazed, plain and heat absorbing glass

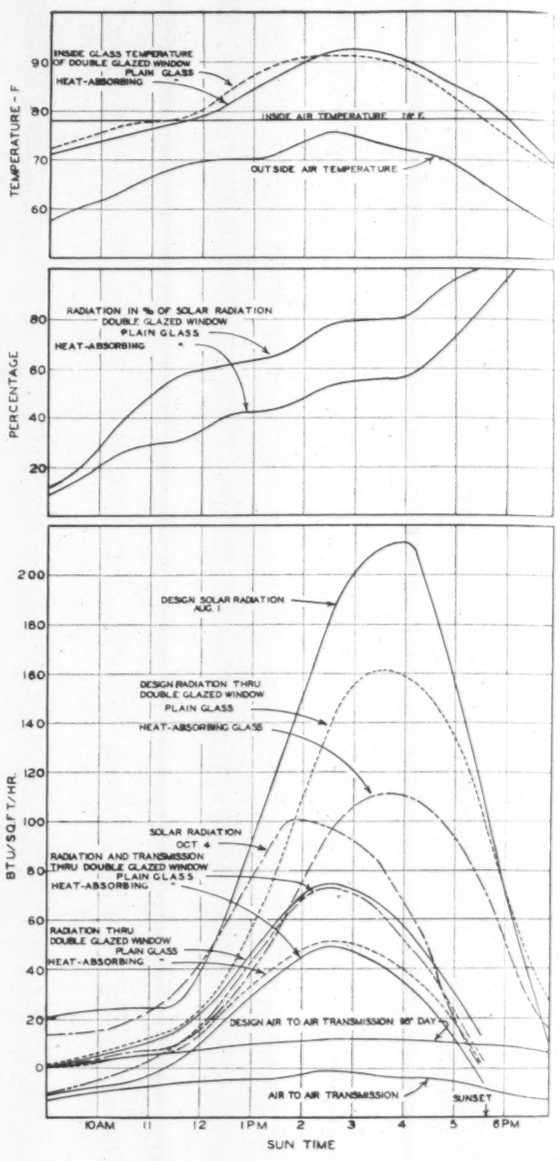


Fig. 9—Solar radiation heat gain relationships for west, unshaded, double-glazed windows (one glazed with plain glass both sides; the other glazed with plain glass on inside and heat absorbing glass on the outside)

transmission gain from the third column multiplied by 0.6.

While the result of this study adds considerably to the knowledge of heat gain through western windows, the few days during the past summer when the solar radiation even approached *design conditions* serve to emphasize that the results should be accepted with some reservation and that further study of some of the window arrangements is desirable. This is particularly true of the results for August 17, September 18, shown in Figs. 5 and 6, when the observed solar radiation deviated considerably from *design conditions*.

The results for western exposures before about 11 a. m., and following approximately one-half hour before sunset, are at times confusing, because of the small magnitude of the effects observed and the probable error in their measurement. This is particularly true for the percentage values given. It is believed, however, that the results even for these periods serve some useful purpose as indications of probable values and trends. It should be emphasized, however, that the data for these periods are of no great value for design purposes and should be considered of academic, rather than practical value.

The curves frequently serve to emphasize the lag between the rate of the solar radiation effect on the outside of the window and the rate at which the heat was extracted by the melting ice. Examples are, the erratic percentages observed during the early hours, before the sun became effective on the west wall, and around sunset, when the absorption of heat by the cooling system was still high and the sun effect was either low or had ceased to exist at all. These peculiarities give high percentages which are hard to justify until the low magnitude of the actual values entering into the percentages and the effect of the lag are considered. In this connection it should be emphasized that unusual care was taken in this study to

Table 3—*Design Heat Gain Data for Several Window Arrangements on August 1, at 40 Deg Latitude; Plain 3/16-in. Sheet Glass and Wood Sash, Unless Otherwise Stated*

Sun Time	Solar Radiation August 1 40 Deg Lat. West Window	Air to Air Transmission 95 F Day	Design Radiation Gain in Btu per Square Foot per Hour and in Per Cent of Design Solar Radiation Intensity on Window																												Solar Radiation August 1 40 Deg Lat. South Window
			West Window																				South Window								
			Unshaded One Light		Complete Shading		Outside Awning Dark Colored		Outside Venetian Blind [a] Light Colored		Shading Screen Outside Dark Colored		Shading Screen Outside Dark Colored Venetian Blind [b] Inside Aluminum Finish		Inside Venetian Blind [b] Aluminum Finish		Inside Roller Shade [c] Dark Green		Single Light Heat Absorbing Glass (Unshaded)		12-Light Wood Sash (Unshaded)		12-Light Steel Sash (Unshaded)		Double Glazing				12-Light Unshaded		1-Light Unshaded	
																									Two Sheets Plain Glass		One Sheet Plain Glass and One Sheet Heat Absorbing Glass[d]					
Sun Time	Btu	Btu	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu	Per Cent	Btu
5–6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.50	24.8	0.72	35.9	2.0
6–7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.8	55.8	3.0	60.0	5.0
7–8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.4	62.0	13.5	67.5	20.0
8–9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	30.0	62.5	32.8	68.4	48.0
9–10	22	3.0	4.0	18.3	0.44	2.0	1.7	7.7	1.9	8.8	1.3	6.0	0.9	4.1	5.3	24.0	6.8	30.7	3.3	14.8	1.4	6.5	1.9	8.5	3.6	16.5	2.9	13.0	50.4	63.0	56.2	70.2	80.0
10–11	24	6.2	10.5	43.7	1.20	5.0	9.4	39.4	9.0	37.5	2.0	8.2	1.7	7.1	6.3	26.4	10.0	41.7	7.4	30.7	9.5	39.5	10.9	45.3	9.5	39.6	6.2	26.0	67.5	67.8	72.8	73.2	99.5
11–12	25	9.8	15.5	62.1	0.55	2.2	15.1	60.5	14.6	58.3	2.7	11.0	2.4	9.6	7.1	28.2	15.1	60.4	8.3	33.0	12.0	48.0	13.3	53.1	14.0	56.0	7.4	29.6	79.3	70.8	85.3	76.2	112.0
12–1	60	13.0	39.8	66.4	1.14	1.9	29.8	49.7	29.3	48.8	7.3	12.2	6.6	11.0	20.7	34.5	38.8	64.6	26.6	44.3	36.5	60.8	36.5	60.6	36.1	60.1	24.1	40.2	77.3	69.0	81.8	73.0	112.0
1–2	123	15.0	88.4	71.9	2.00	1.6	34.8	28.3	39.1	31.5	18.5	15.0	17.1	13.9	55.3	45.0	83.9	68.2	57.9	47.1	89.2	72.5	87.7	71.3	79.7	64.8	53.1	43.2	64.9	65.2	70.9	71.3	99.5
2–3	180	18.0	153.0	85.0	8.82	4.9	41.2	22.9	57.2	31.8	32.8	18.2	29.3	16.3	106.2	59.0	144.4	80.2	104.6	58.1	141.3	78.5	147.1	81.7	138.6	77.0	94.7	52.6	50.8	63.5	56.2	70.2	80.0
3–4	206	18.0	175.5	85.2	5.97	2.9	46.8	22.7	67.6	32.8	48.4	23.5	44.7	21.7	136.0	66.0	166.0	80.6	120.1	58.3	163.3	79.3	172.0	83.5	163.3	79.3	112.9	54.8	48.0	100.0	53.2	110.8	48.0
4–5	186	17.5	165.9	89.2	4.70	2.5	41.3	22.2	62.1	33.4	58.6	31.5	53.4	28.7	133.9	72.0	153.5	82.5	113.8	61.2	153.1	82.3	157.7	84.8	151.0	81.2	104.1	56.0	26.0	130.1	30.9	154.7	20.0
5–6	120	15.0	123.0	102.5	3.24	2.7	34.3	28.6	43.4	36.2	52.0	43.3	45.4	37.8	98.4	82.0	115.2	96.0	84.0	70.0	135.6	113.0	123.4	102.8	114.0	95.0	76.8	64.0	7.5	150.0	8.1	162.0	5.0
6–7	40	12.2	43.9	109.7	2.48	6.2	19.3	48.3	28.9	72.2	27.7	69.2	27.2	68.1	36.4	91.0	46.0	115.0	32.8	82.0	49.8	124.4	48.0	120.0	.....	.....	.....	.....	3.0	150.0	3.3	165.0	2.0

a—So arranged as to keep sun off window.
b—Venetian blind slats at 45 deg.
c—Shade one-half drawn.
d—Double-glazed window—plain glass inside; heat absorbing glass outside.

reduce this lag effect by installing the cloth drapes to absorb the solar radiation and quickly impart its heat to the air while in most practical applications this lag effect will be much greater. An example of this is shown by an office cooling study[5] made by the Laboratory, which indicated that a considerable percentage of the solar radiation entering the room during the afternoon was still in the concrete floor on which it fell at 5 p. m. In this connection attention is called to Fig. 4 showing from 18 to 20 Btu charged to solar radiation on the window, still being absorbed by the cooling system at 7:30 p. m., or after sunset, even though the outside air and inside glass surface temperatures were at the time lower than the inside air temperature.

[5] ASHVE Research Report No. 1002—Cooling Requirements of Single Rooms in a Modern Office Building, by F. C. Houghten, Carl Gutberlet and Albert I. Wahl. (ASHVE Transactions, Vol. 41, 1935, p. 53.)

W. L. LYNCH NAMED TRUSTEE OF SAVINGS BANK

William L. Lynch, Rome, N. Y., was elected a trustee of the Rome Savings Bank at a meeting of the board recently. He, with E. Leslie Barnard, succeed the late S. H. Beach and the late Carl Simon. Mr. Lynch, who is president and treasurer of Rome-Turney Radiator Co., was graduated from the Rome Free Academy. He joined the ASHVE in 1928, and in 1929 was named a director of the Farmers' National Bank and Trust Co., having been employed there in his earlier years. Soon after he entered the services of the Rome-Turney Radiator Co., he advanced rapidly and was elected secretary of the firm in 1913.

Upon his attainment of the control of the majority of the stock in the local concern in 1921, he became its president. Mr. Lynch is a member of the Teugega Country Club, Rome Lodge 96, B.P.O.E., and the Knights of Columbus. He is immediate past president of the Kiwanis Club, and besides being a member of the American Society of Heating and Ventilating Engineers he is also a member of the *American Society of Refrigerating Engineers.*

Boiler Testing Codes

By J. F. McIntire,* Detroit, Mich.

AT the 2nd Annual Meeting of the Society in 1896 the first discussion of boiler ratings occurred and this perennial topic was a matter of debate through the early years of the Society. Finally in 1909 the Society assigned the problem of rating house-heating boilers to a joint committee consisting of the Committee of Standards and the Committee on House-Heating Boilers.

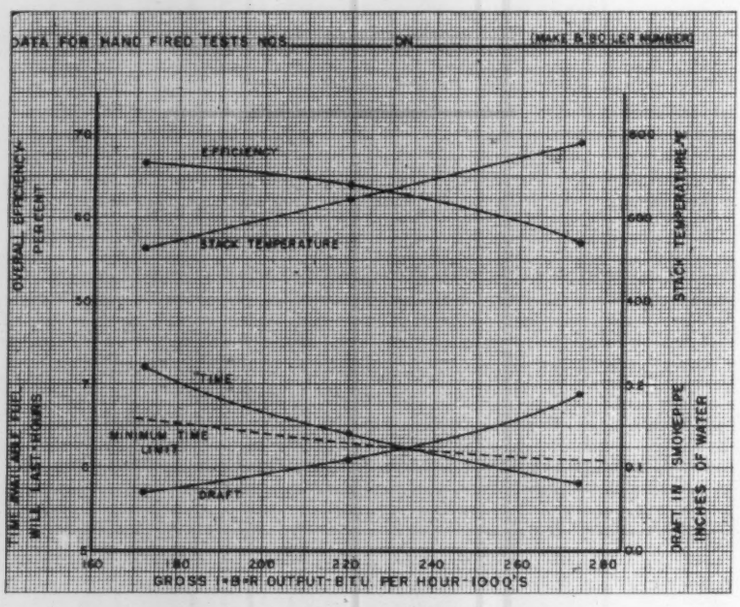


Fig. 1—Sample curves for hand-fired tests

Committee after committee struggled with yearly revisions until 1921 when it became apparent that the question of objective must be settled and a decision made to draft a testing code, a rating code, or both.

The Code for Testing Low Pressure Steam Heating Boilers, Revision of 1923, contained such decision because it stated: "Object—Standard method for conducting and reporting heat efficiency at various rates of steaming".

This code was well done as it represented not only the work of an excellent committee but the contributions of previous committee men, and valuable information had been gained from laboratories which had tried the previous codes.

Although the testing code satisfied those who desired a performance curve, it did not specify or suggest a rating. The Society realized the need for a rating code and during the late twenties, a committee, free from contamination of manufacturer affiliation (the writer had been on previous committees), tried earnestly to supply an acceptable rating formula. The rating recommendations of this committee were rejected because confusion still existed between testing and rating. The ASHVE Standard Code for Rating Steam Heating Solid Fuel Hand-Fired Boilers was adopted in January 1929 and revisions were made and approved in April 1930.

These boiler testing codes have served a useful purpose to date, but the rating code has not been widely used.

The *Steel Heating Boiler Institute* has given their *SHBI* ratings which are based on structural dimensions. As long as the *SHBI* code gives general satisfaction to the public and the industry, the writer believes the ASHVE is justified in recognizing its usefulness.

Net load recommendations of the *Heating, Piping and Air Conditioning Contractors National Association* likewise has served the cast-iron boiler industry as a commercial guide, but like the *SHBI* code it is based on structural dimensions.

The *Institute of Boiler and Radiator Manufacturers,* a trade association, representing practically all producers of cast-iron boilers in the United States, decided in 1938 to develop a code for testing and rat-

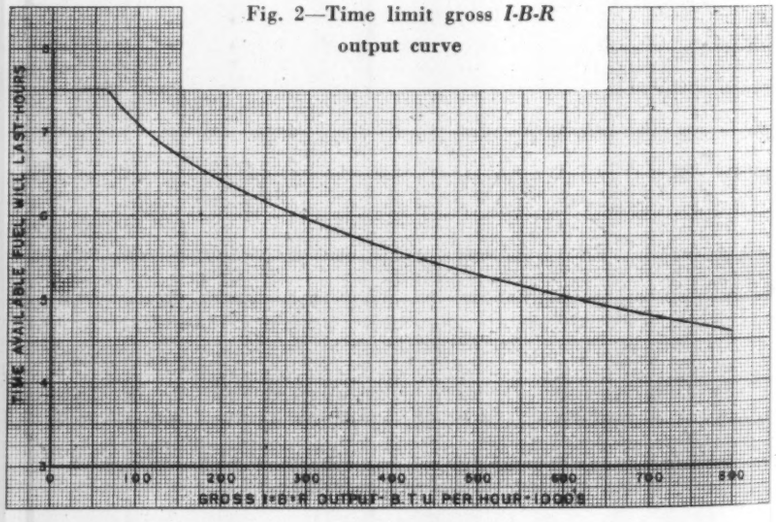


Fig. 2—Time limit gross *I-B-R* output curve

*Vice-President, United States Radiator. MEMBER of ASHVE.

Presented at the 47th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Kansas City, Mo., January, 1941.

ing boilers which would warrant universal acceptance. As performance was the only basis which could be considered, the first step was to study the ASHVE testing codes. Naturally their adoption would lend prestige to the undertaking. Meetings were held in a research laboratory where boilers were tested in accordance with the codes. Equipment and technique were studied. Results were analyzed. Confidential data and experience were contributed freely by the engineers of member companies.

Performance was found to be influenced by so many variables that fixing of one only could not provide a satisfactory rating. It became apparent that several very definite limits should be established. For hand-fired boilers, as an example, these include minimum over-all efficiency, time available fuel will last, draft control to correspond to chimney height, etc. Fig. 1 shows sample curves for hand-fired tests, and Fig. 2 shows a time limit curve. Fig. 3 shows a section of curves used to set maximum heights and minimum areas of chimneys.

Figs. 4 and 5 show curves which serve as a guide for regulation of the draft to temperature to correspond with the *chimney* specified by manufacturer. These curves are based on the field experience of the manufacturers and represent the best data available today. Insufficient data were available to extend the curves beyond 1150 F.

The ASHVE could render a valuable service to the heating industry by undertaking an extensive investigation of chimney performance and it is felt that the manufacturers of cast-iron and steel boilers, warm-air furnaces, stokers and oil burners would support such a project.

The ASHVE testing code for oil-fired boilers had to be revised to

Fig. 3—Stack height and stack area gross *I-B-R* output curve

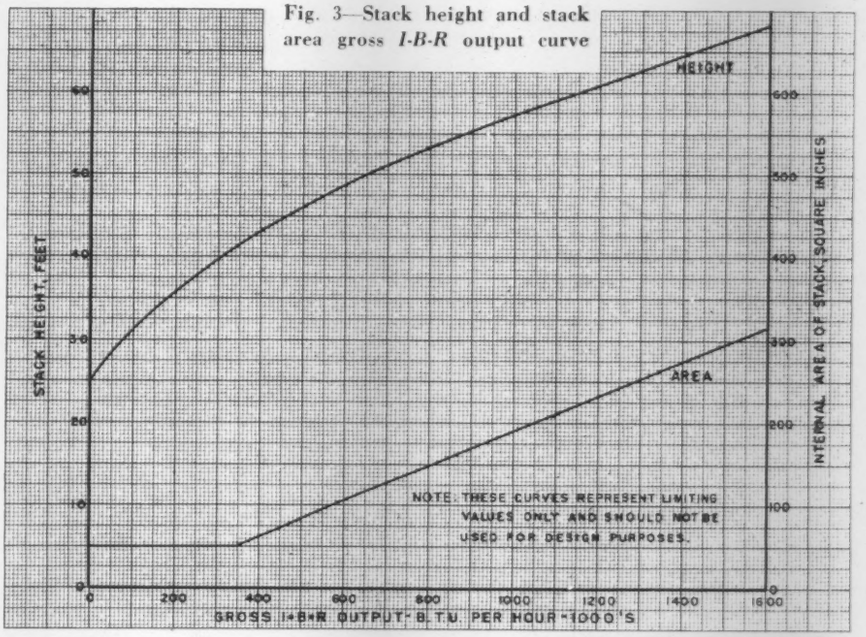

HEIGHT
AREA
NOTE: THESE CURVES REPRESENT LIMITING VALUES ONLY AND SHOULD NOT BE USED FOR DESIGN PURPOSES.
STACK HEIGHT, FEET
INTERNAL AREA OF STACK, SQUARE INCHES
GROSS I-B-R OUTPUT-B.T.U. PER HOUR-1000'S

Fig. 4 — Stack height - draft - temperature curve

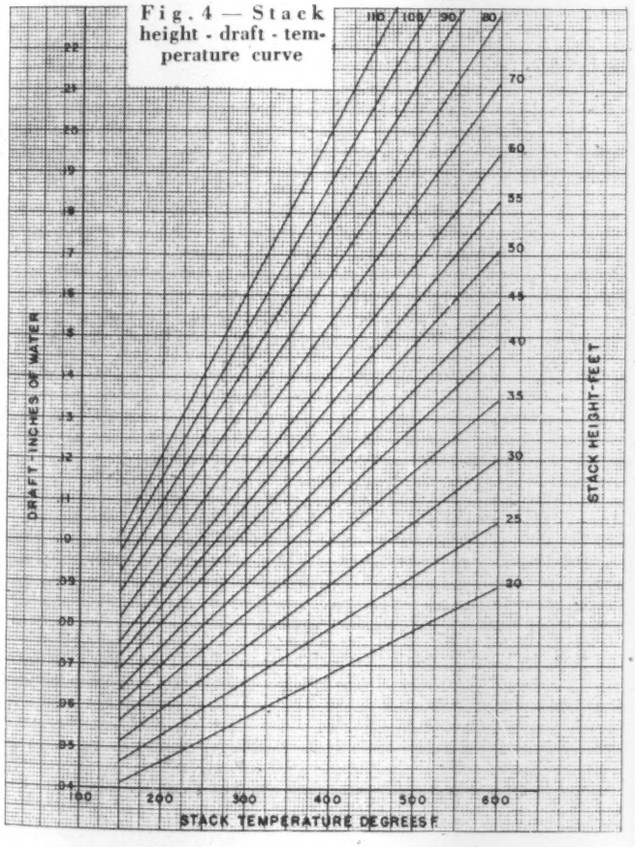
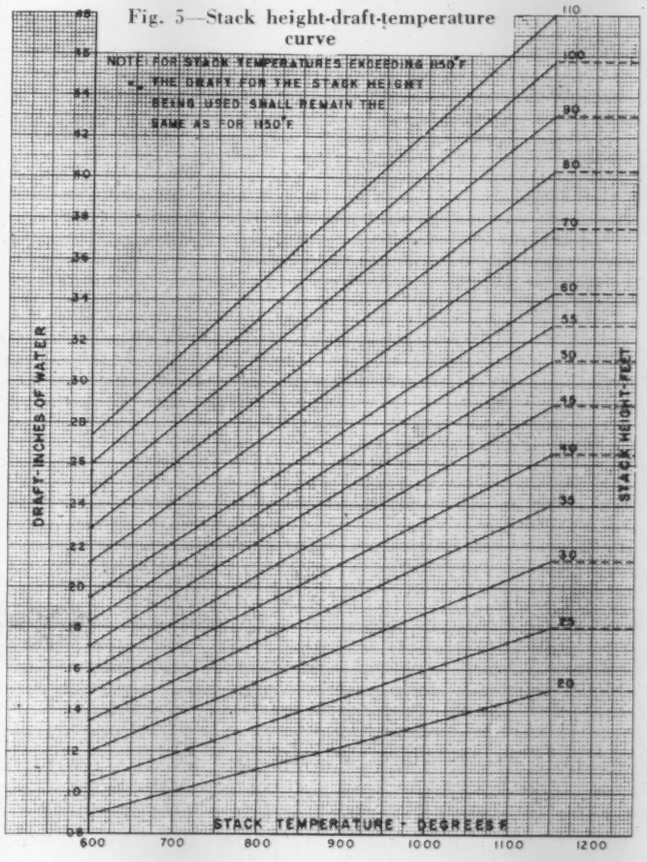


Fig. 5—Stack height-draft-temperature curve


NOTE: FOR STACK TEMPERATURES EXCEEDING 1150°F THE DRAFT FOR THE STACK HEIGHT BEING USED SHALL REMAIN THE SAME AS FOR 1150°F
DRAFT-INCHES OF WATER
STACK HEIGHT-FEET
STACK TEMPERATURE - DEGREES F

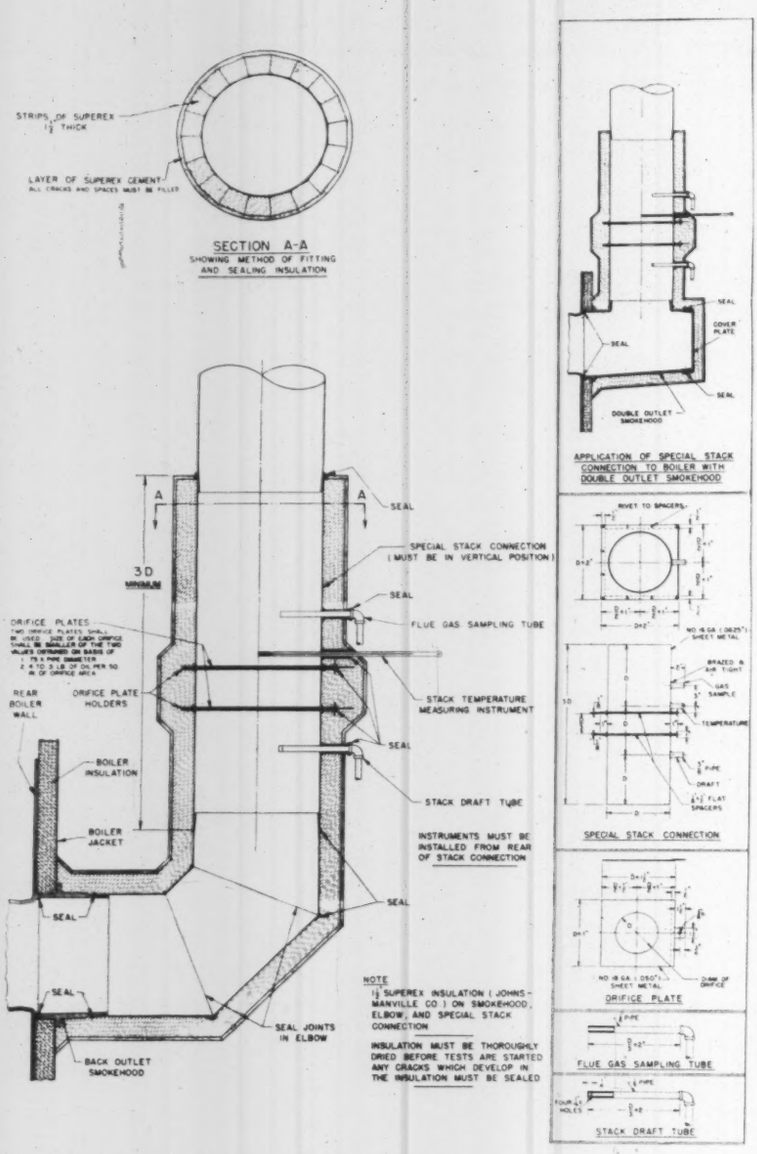

STRIPS OF SUPEREX 1½ THICK
LAYER OF SUPEREX CEMENT
SECTION A-A
SHOWING METHOD OF FITTING AND SEALING INSULATION
APPLICATION OF SPECIAL STACK CONNECTION TO BOILER WITH DOUBLE OUTLET SMOKEHOOD
SEAL
COVER PLATE
DOUBLE OUTLET SMOKEHOOD
SPECIAL STACK CONNECTION (MUST BE IN VERTICAL POSITION)
FLUE GAS SAMPLING TUBE
STACK TEMPERATURE MEASURING INSTRUMENT
STACK DRAFT TUBE
ORIFICE PLATES
ORIFICE PLATE HOLDERS
REAR BOILER WALL
BOILER INSULATION
BOILER JACKET
INSTRUMENTS MUST BE INSTALLED FROM REAR OF STACK CONNECTION
SEAL JOINTS IN ELBOW
BACK OUTLET SMOKEHOOD
NOTE
½ SUPEREX INSULATION (JOHNS-MANVILLE CO.) ON SMOKEHOOD, ELBOW, AND SPECIAL STACK CONNECTION
INSULATION MUST BE THOROUGHLY DRIED BEFORE TESTS ARE STARTED ANY CRACKS WHICH DEVELOP IN THE INSULATION MUST BE SEALED
SPECIAL STACK CONNECTION
ORIFICE PLATE
FLUE GAS SAMPLING TUBE
STACK DRAFT TUBE

Fig. 6—Application of special stack connection to boiler with back outlet smokehood

insure an accurate control of the performance in line with the rating code requirements. For example, the CO_2 must be held at 10 per cent, a maximum flue gas temperature set, a minimum over-all efficiency required, allowable draft loss established, and a maximum heat release fixed.

The difficulty experienced in reading flue gas temperatures accurately led to the development of the double orifice plate arrangement illustrated in Fig. 6.

The true temperature of the gas is obtained by this method and the readings will run 50 to 100 deg higher than those taken at same location with bare pipe and without orifice plates. Engineers should take into account this difference between field and laboratory test conditions. Fig. 7 shows sample curves for oil fired tests. The draft loss is limited by curve Fig. 8.

The draft in the fire box shall be maintained at 0.02 in. of water.

The *I-B-R* testing code serves its purpose as a basis of rating and the boiler testing codes of the ASHVE serve for general use. Nothing can be gained by consolidating them, but the writer does recommend that the ASHVE codes be reviewed with the thought of incorporating any improvements which may be indicated by the work of the *I-B-R*.

The *I-B-R* rating code provides the method and procedure for determining the gross output and net rating of a heating boiler. The gross output in Btu is determined by actual test as already discussed. The net rating is determined from the gross output. Fig. 9 shows a part of the conversion curve.

The difference between the gross

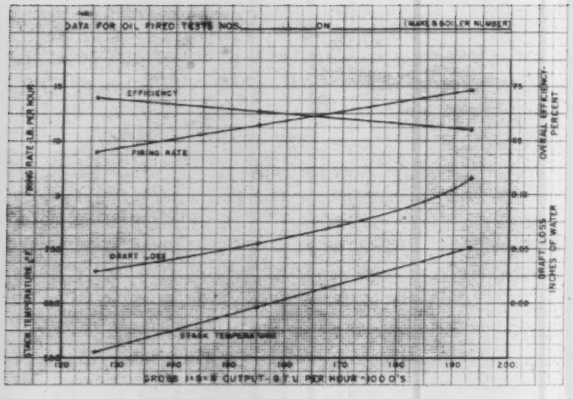


Fig. 7—Sample curves for oil fired tests

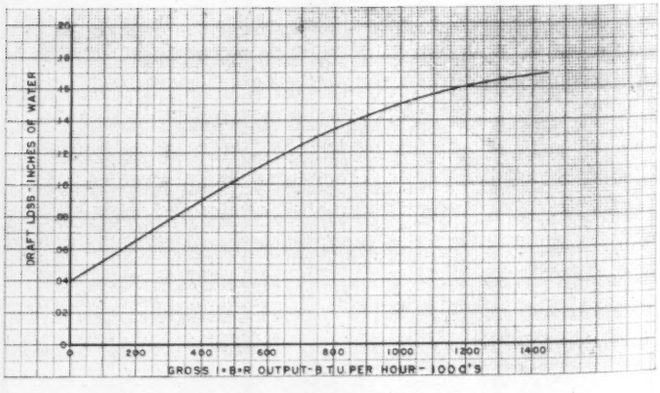


Fig. 8—Draft loss-gross *I-B-R* output curve

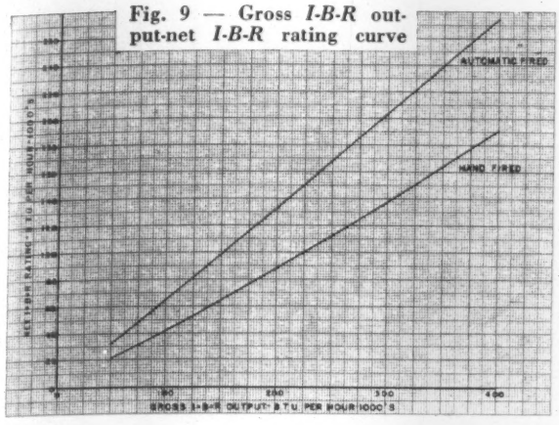


Fig. 9 — Gross *I-B-R* output-net *I-B-R* rating curve

and net is the allowance for piping and pickup. Naturally a larger percentage is required for the small installations. The factors used compare favorably with those contained in the ASHVE Code of Minimum Requirements for Heating and Ventilation of Buildings adopted in 1925. Automatic fired units require less pick-up factor, therefore show a larger net for a given gross than does the hand-fired.

The net rating is expressed in terms of square feet of steam and/or hot water radiation and Btu per hour.

Hand-fired bituminous coal ratings are the same as hand-fired anthracite. Stoker fired ratings, both anthracite and bituminous, cannot be more than those developed with oil.

Gas-fired units shall have the same gross output in Btu as AGA approved ratings, but the net *I-B-R* ratings shall be determined from gross output—net rating *I-B-R* curves such as Fig. 9.

The *I-B-R* testing and rating code, published by the *Institute of Boiler and Radiator Manufacturers,* is a comprehensive document, and much important detail has been omitted in this discussion.

The *I-B-R* Testing and Rating Code seems to be the answer sought by our committees for many years. Its general acceptance and proved practicability would seem to justify our lending it our endorsement.

DOCTOR OF SCIENCE DEGREE CONFERRED ON F. C. HOUGHTEN

Ferry C. Houghten, Director of the Research Laboratory of the American Society of Heating and Ventilating Engineers at Pittsburgh, Pa., was awarded an honorary degree of Doctor of Science by Olivet College, Olivet, Mich., at its annual Founders' Day convocation on February 24, 1941.

Mr. Houghten was born in Troy, Mich., in 1888, and after his graduation from Olivet College in 1913 with an A. B. degree, he received a Master of Science Degree at the University of Washington in 1915. Following an appointment with the U. S. Bureau of Mines, Pittsburgh, Pa., he became associated with the Research Laboratory of the Society, and in September, 1925, became its Director.

Prof. Gale Young at Olivet, in presenting Mr. Houghten before the ceremonies, stated that it was the custom of colleges from time to time to take explicit notice of outstanding achievements on the part of their friends and alumni, and to record their recognition in the form of honorary degrees, and this was just such an occasion at Olivet. The guest of honor and principal speaker he announced was Ferry C. Houghten, a man eminently deserving of such an award. He further called attention to the fact that Mr. Houghten's achievements are outlined in the pages of *American Men of Science* and in *Who's Who,* and represented in his long list of publications, many of which have been translated into other languages.

F. C. Houghten
Pittsburgh, Pa.

Professor Young further explained that it was not his purpose to review Mr. Houghten's works in any detail, as a worthwhile career cannot be encompassed in a few pages or compressed into a few minutes of declamation. It is something that stretches through a lifetime of labor and into the years to come. It is something whose worth is measured in terms of the benefits it brings for all mankind, of the additions it makes to man's store of knowledge, and of the new tools it forges for those who follow.

Mr. Houghten is an engineer and an applied scientist, and it is perhaps in these fields that the time binding aspect of man's activity is most clearly seen. It has been said that what is great in man is that he is a bridge and not a goal; that he is a rope stretching from the jungle toward the stars. Times of war remind us that it is a rope over an abyss—a dangerous crossing, a dangerous looking back, a dangerous trembling and halting. Heavy boots and white faced women—the march of man, and the bridge shudders perilously beneath him. It is a welcome reassurance indeed that we have men like Mr. Houghten to remind us that, buffeted as it may be, that bridge is still there; that the surge of mind and man is still going forward. To such men as he we intrust our hopes that it will continue to go forward, and our most fervent prayers that that bridge shall not perish from the earth.

Acting on behalf of the faculty and the Board of Trustees of Olivet College, Professor Young presented Mr. Houghten to Pres. Joseph Brewer for the honorary degree of Doctor of Science.

President Brewer in awarding the honor to Mr. Houghten made the following citation:

> Ferry C. Houghten, loyal son of Olivet whom we delight to honor; teacher and scholar whose work amongst and with his fellow men has contributed greatly to the health, comfort, welfare and knowledge of mankind, now by virtue of the authority vested by the State of Michigan in the Board of Trustees of Olivet College and by them delegated to me as President, I confer upon you the degree of Doctor of Science and admit you to all the rights, honors, privileges and responsibilities appertaining thereunto, and in token thereof I present to you this diploma and invest you with this hood.

Warm-Air Furnace Codes

By F. L. Meyer,* Peoria, Ill.

SUMMARY—A resumé is given of the progress made in the past 30 years in the development of warm air furnace codes. As the result of research in 1922 a code for gravity systems was devised, and through the application of fans to warm air furnaces a code was developed in 1932 covering the design and installation of mechanical warm air heating systems. The desirability of developing a test method for the rating of forced warm air furnace systems is emphasized with the need for additional laboratory studies to develop necessary testing procedure and technique

AS LONG as 30 years ago the manufacturers of warm-air furnaces, engineers and installers made various efforts to establish a practical set of rules to govern the rating and installation of gravity warm-air furnaces. By that time competition in this industry was keen, and the lack of scientific data regarding performance resulted in many irregularities which created dissatisfaction in the minds of the public as well as in those of the industry. In 1918 the *National Warm Air Heating and Ventilating Association* (now the *National Warm Air Heating and Air Conditioning Association*) entered into an agreement with the University of Illinois Engineering Experiment Station to conduct cooperative research on warm-air furnaces in an endeavor to obtain actual technical data that would lead to higher and more uniform standards in this important public service, and the investigations have been conducted there continuously since that time. In 1923, to further the research work, a Research Residence was erected by the Association at Urbana.

As a result of this research, which has been recorded in various bulletins of the Engineering Experiment Station, the *Standard Gravity Code for the Design and Installation of Gravity Warm-Air Heating Systems* was first published by the Association in 1922. The eleventh edition of this code was recently issued.

In the 1920's the application of fans to warm-air furnaces gained considerable headway. By 1930 the industry was actively advocating forced warm-air heating. In 1932 the association published its first code to govern such systems. The *Technical Code for the Design and Installation of Mechanical Warm-Air Heating Systems* was first published in 1937; it is now in its third edition.

As this paper deals essentially with coal-burning furnaces, it may be well at this point to state that, while the codes mentioned cover entire heating systems, reference will hereafter be made only to portions of such codes dealing with furnace ratings.

*Vice-President, The Meyer Furnace Co. MEMBER of ASHVE.

Presented at the 47th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Kansas City, Mo., January, 1941.

Gravity Warm-Air Furnaces

The original work at the University of Illinois, leading to the origin of the Standard Gravity Code, was conducted in a laboratory plant set up for the purpose. As may be observed in Fig. 1, this plant has the essential characteristics of a gravity system installed in an ordinary residence.

This early investigation demonstrated that in the case of a gravity furnace a unique relationship exists between:

1. Combustion rate
2. Draft
3. Register air temperature
4. Weight of air flowing
5. Capacity
6. Efficiency

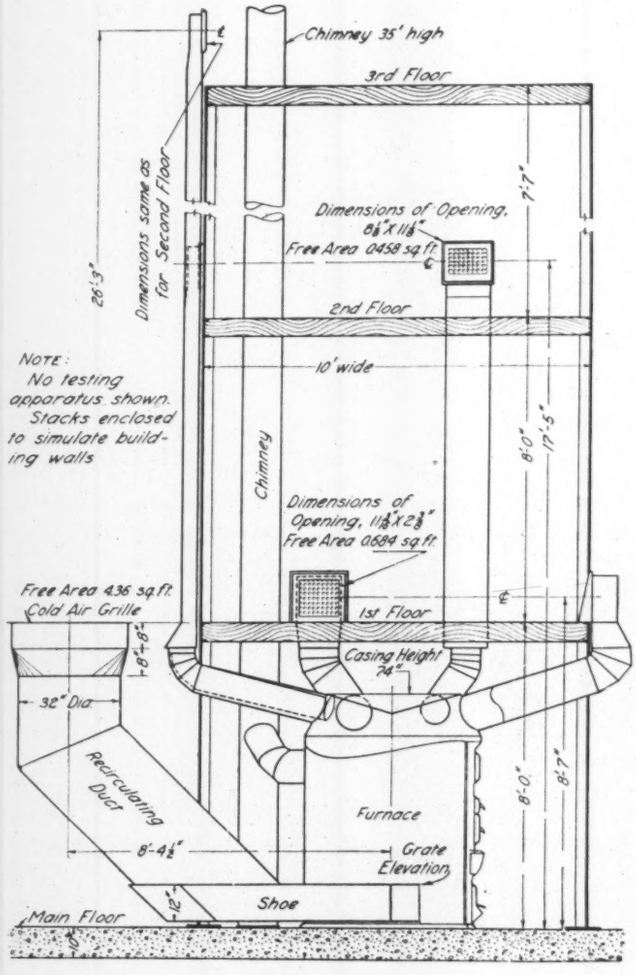


Fig. 1—Line diagram of furnace plant for testing gravity warm-air furnaces

such that when the first three items are stated for any given furnace the last three items can be definitely stated.

Over a period of 14 years a large number of typical furnaces were tested, and the data shown in Fig. 2 were obtained. It will be noted that the performance of the furnace is given in terms of two physical dimensions, namely heating surface and grate area. These data apply only to furnaces of the commonly used types, in which it was found that the total amount of heating surface was of greater importance than the distribution of the heating surface. The data are not applicable to furnace construction which deviates widely from commonly accepted designs.

Employing these data, the equation for the heat delivery at the warm-air registers was set up as:

$$H = \frac{G\,C\,F\,E\,E'\,E''}{144}\,[1+0.02\,(R-20)]$$

in which,

H = Heat loss from building, Btu per hour
G = Grate area in square inches
C = Combustion rate, in pounds of coal per square foot of grate per hour
F = Heating value of the coal, Btu per pound
E = Efficiency at bonnet
E' = Efficiency of duct transmission
E'' = Factor of safety
R = Ratio of heating surface to grate area

By the substitution of numerical values, based on test results, of $C = 7.5$, $F = 12{,}790$, $E = 0.55$, $E' = 0.75$ and $E'' = 0.866$, and converting to leader pipe area by the equation, $H = 136L$, the furnace rating formula of the Standard Gravity Code is expressed as:

$$L = 1.75\,G\,[1 + 0.02\,(R-20)]$$

in which,

L = Leader pipe area in square inches
G = Grate area in square inches
R = Ratio of heating surface to grate area

The rating formula strictly holds only for furnaces that will give a register air temperature of 175 F with a combustion rate of 7.5 lb of coal burned per square foot of grate area per hour. Furthermore, from the data shown in Fig. 2 the rating formula was limited to furnaces in which the ratio of heating surface to grate area was not less than 15 to 1 nor greater than 30 to 1.

Since the adoption of this formula by the association, it has been almost universally used, and its application has been highly successful. Coal-burning furnaces rated according to it have an ample margin of safety. The chaotic conditions, which existed in the field, have been largely straightened out, and all ratings are on a comparable and equable basis, resulting from actual test data. The Standard Gravity Code has been approved and adopted by the ASHVE.

Forced Warm-Air Furnaces

When a fan is applied to a furnace it not only may increase the efficiency of heat transfer at what may be considered as normal combustion rates for gravity circulation, but also, with an increase in air flow and sufficient chimney draft, it makes possible the use of higher combustion rates with resulting greater output, without increasing the temperature of the heat transfer surface. Also, the duct losses are lower because of lower temperature air and smaller amount of duct surface.

The rating formula for forced-air furnaces, as given in the Technical Code, is a slight modification of that in the gravity code. For a coal-burning furnace of the conventional type the formula is:

$$H = \frac{G\,C\,F\,E\,E'}{144}\,[1+0.02\,(R-20)]$$

in which,

H = Heat loss from building, Btu per hour
G = Grate area in square inches
C = Combustion rate, in pounds of coal per square foot of grate per hour
F = Heating value of coal, Btu per pound
E = Efficiency at bonnet
E' = Efficiency of duct transmission
R = Ratio of heating surface to grate area

The Technical Code suggests the use of $C = 7.5$, $F = 12{,}000$, $E = 0.65$, $E' = 0.85$ in the foregoing formula, for average conditions. This method of rating is gaining in usage.

Strictly speaking, however, the rating of a forced warm-air furnace should be determined by test, with the air quantity circulated by the fan also stated. That is, E, the efficiency at the bonnet, will depend on the quantity of air flowing, which can be independently varied. If furnaces are properly designed and baffled, and sufficient air comes in intimate contact with the heating surface, efficiencies greater than 65 per cent are attainable. Furnaces operating under the latter conditions will be penalized to some extent by the suggested value of efficiency in the Technical Code. However, unless actual tests of a sufficiently comprehensive nature show that higher efficiencies can be readily obtained, it

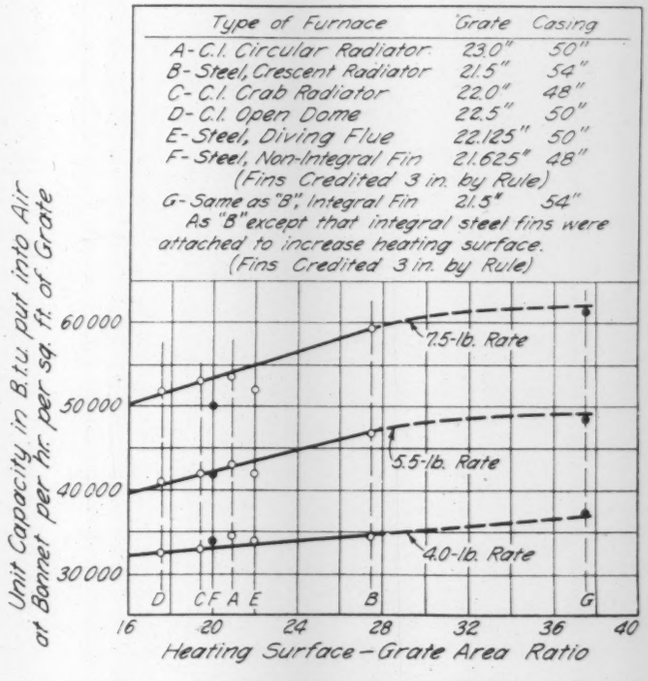

Type of Furnace
Grate
Casing
A-C.I. Circular Radiator 23.0" 50"
B-Steel, Crescent Radiator 21.5" 54"
C-C.I. Crab Radiator 22.0" 48"
D-C.I. Open Dome 22.5" 50"
E-Steel, Diving Flue 22.125" 50"
F-Steel, Non-Integral Fin 21.625" 48"
(Fins Credited 3 in. by Rule)
G-Same as "B", Integral Fin 21.5" 54"
As "B" except that integral steel fins were attached to increase heating surface.
(Fins Credited 3 in. by Rule)
7.5-lb. Rate
5.5-lb. Rate
4.0-lb. Rate
60 000
50 000
40 000
30 000
D C F A E B G
16 20 24 28 32 36 40
Unit Capacity in B.t.u. put into Air at Bonnet per hr. per sq. ft. of Grate
Heating Surface-Grate Area Ratio

Fig. 2—Curves correlating unit capacity and ratio of heating surface to grate area for seven types of furnaces

is not deemed advisable to go beyond the recommendations made.

The same formula should be used in selecting a furnace for a stoker-fired installation. In some cases a value for E of 0.70 has been used. In general, though, the test results in the Research Residence have indicated the advisability of using a value for E of 0.65. A slightly oversized furnace in a stoker-fired installation will prove to be advantageous.

Laboratory Test Method

Based on the premise that ratings of forced-air furnaces should be developed by test, there has been submitted to the association by a subcommittee of its Research Technical Advisory Committee a *Tentative Recommended Code for Testing and Rating Oil-fired, Fan-Furnace Combinations*. Fig. 3 shows the recommended test plant.

Aside from determining the heat input to the furnace, the type of fuel is immaterial, and it is proposed to employ this general test arrangement for coal and gas fuels as well. Thus it is possible to test and rate each fan-furnace combination for given values of:

1. Combustion rate
2. Draft
3. Register air temperature, and
4. Weight of air flowing.

The tentative code is still in the formative stage, and present plans call for a laboratory study of the proposed test method.

In general, for a forced warm-air furnace, whatever rating formula or code is used, the final result will have to be based ultimately on test data. The technique of testing and rating may be beyond the limited capacities of any given plant. Furthermore, the method of operating the tests may differ with each individual company. However, there should be adequate assurance that ratings will be unbiased, if made under individualistic effort.

Any future program of work that might be necessary in this industry in the way of testing or rating warm-air furnaces would probably involve studies of stoker-fired furnaces, furnaces having exceedingly large amounts of heating surfaces, and studies of the effects of baffling of the casing. The *National Warm-Air Heating and Air Conditioning Association* stands ready to cooperate with other groups in any work of this nature.

The author wishes to acknowledge the assistance of Professors A. P. Kratz and S. Konzo in the preparation of this paper.

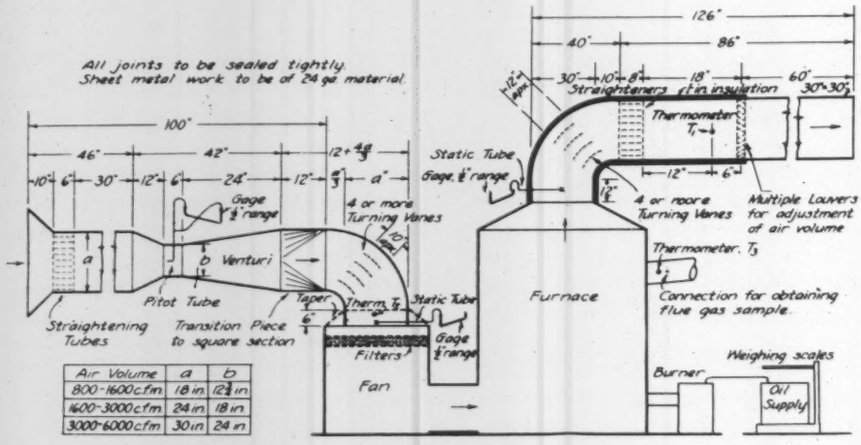


Fig. 3—Line diagram showing arrangement of apparatus suggested for testing fan-furnace, forced-air heating units

NEBRASKA CHAPTER ANNOUNCES OFFICERS

The following have been elected to hold office for the coming year as officers of the Nebraska Chapter of the Society:

President—Frederick Organ.
Vice-President—H. W. Stanton.
Treasurer—G. E. Merwin.
Secretary—C. E. Wiser.
Board of Governors—E. F. Adams, Henry Kleinkauf and W. R. White.

No regular meeting headquarters has been established for the Nebraska Chapter, but it is planned to hold a meeting on the second Tuesday of each month, in one of the local hotels, starting with dinner at 6:30.

At the January 15 meeting the guest speakers were, S. Frank Cox, technical director of the Double Glazing Division, Pittsburgh Plate Glass Co., and J. C. Kohl, technical adviser on glass block, Pittsburgh Corning Glass Co. They gave a very interesting illustrated talk on glass block and double glazing.

SOUTHERN CALIFORNIA CHAPTER MEETS

January 8, 1941. The Southern California Chapter of the Society held its January meeting at Steven's Nikabob Café, Los Angeles, and 27 members and guests were present.

The main topic discussed at this meeting was Electric Motors and Their Applications, followed by a general discussion. J. B. Colesworthy, Westinghouse Electric and Mfg. Co., spoke on the constant speed of 3-phase motors, and Carl Johnson, Sterling Electric Co., talked on slip-ring motors and mechanical variable speed units.

These talks were followed by one on multi-speed motors and motorized gear units, which was rendered by W. H. Hogue, U. S. Electric and Mfg. Co. H. H. Bullock, General Electric Co., also gave an interesting talk on the fractional and integral single-phase motors, and following a general discussion from the floor the meeting was adjourned.

December 11, 1940. The December meeting was also held at Steven's Nikabob Café, Los Angeles, and 34 members and guests were in attendance.

Hot water heating, which was a discussion on the subject of modern development of hot water heating with reference to residence and large industrial jobs, was the topic discussed. The speakers who led the discussion were Glen Miller, Southern California Gas Co., and A. J. Hess, English and Lauer, Inc. Following an interesting general discussion the meeting adjourned.

Codes in the Stoker Industry

By E. C. Webb,* Cleveland, Ohio

SUMMARY—Existing standards in the small stoker industry are reviewed having a special interest to Society members. The development of stoker codes since 1929 is traced, showing advances made towards obtaining wider acceptance. Recommendations are outlined for needful revisions of current codes

THE purpose of this paper, as outlined in the request of the Research Technical Advisory Committee on Solid Fuels for its preparation, is to place before the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS the thoughts of a representative of the stoker industry in regard to the background for the present stoker codes, the accomplishments that these codes have made, and the suggestions for other codes that may be desirable.

There are only a few existing codes pertaining to stokers. These have all been prepared during the past few years as a result of the growth of this industry and the important place it now occupies in the heating field. As the codes are entirely different in their scope, each will be discussed individually.

Code for Testing Stoker-Fired Steam Heating Boilers

In June, 1929, the ASHVE Performance Test Code for Steam Heating Solid Fuel Boilers[1] was adopted by the Society. The ASHVE Standard Code for Testing Steam-Heating Boilers Burning Fuel Oil was then added in 1932 and in 1937 a special committee was appointed to prepare a similar code for automatic stokers. This latter code was adopted by the Society[2] in 1938 and was also adopted the same year by the *Stoker Manufacturers Association* as their standard testing code for stoker-fired steam-heating boilers.

The purpose of this code, as outlined in its introduction, is *to provide a standard method for conducting and reporting tests to determine heat efficiency and performance characteristics.*

As the title of the code implies, it covers the testing of two devices, that is, boiler and stoker. The heat efficiency obtained and reported is, therefore, the combined efficiency of the stoker and boiler and is expressed in percentage of heat in the fuel fired which is delivered at the boiler nozzle when the boiler is normally insulated.

It is felt that this code has served a very useful purpose in outlining a standard procedure for conducting and reporting tests of this type and in general has been well accepted and recognized by the industry. There has been some comment, however, to the effect that the procedure as outlined could be improved, particularly from the standpoint of the practical application of a short test form.

There is also an apparent need for a performance summary that will more clearly show the combustion efficiency of the fuel burning equipment independent of the heat absorbing efficiency of the boiler.

Although the data recorded in the heat balance indicate to a certain extent the individual performance of the stoker and the boiler, there is at present no recognized uniform procedure for showing the influence of the combustion efficiency of the stoker or the heat absorbing efficiency of the boiler on the combined over-all efficiency of the two devices.

It is recognized that the manner in which the heat is applied to a boiler affects its heat absorbing efficiency; also, that the combustion chamber of the boiler has a material effect on the combustion efficiency of the fuel burning equipment. Therefore, one of the units cannot be considered entirely independent of the other. However, it is felt that the outline for reporting the heat balance could be revised to more clearly show the individual performance of the two units. Such a revision in the oil-fired and stoker-fired steam-heating boiler codes should be helpful to the industry, particularly as they are applied to performance specifications and performance tests on some of the larger heating equipment.

It is suggested, therefore, that the Society give consideration to the review of this code, giving special attention to the test procedure and a revision of the outline for reporting the heat balance.

Uniform Stoker Rating

This code[3] was adopted by the *Stoker Manufacturers Association* on November 15, 1937, and is now well accepted by the stoker manufacturers as a basis for rating and applying their equipment. It is also recognized by the *Heating, Piping and Air Conditioning Contractors National Association* and is published in their pamphlet entitled *Net Load Recommendations for Heating Boilers.*

Convenient charts and tables are provided for selecting the stoker rating required for the load that it is expected to carry. These data are based on factors established by the Association as representing average normal performance.

Prior to the adoption of this uniform method of rating, there was considerable variation in the procedure followed by the different manufacturers as well as heating contractors and others specifying the selection of stoker equipment. It is thought that the code has served a very useful purpose in placing on a more nearly uniform basis the methods of rating and size selection of stoker equipment.

Minimum Setting Heights

During the past few years the subject of stoker setting heights has been given considerable attention due to the regulations that have been established by the smoke regu-

*Engineering Service Manager, Iron Fireman Mfg. Co. MEMBER of ASHVE.

[1]ASHVE Performance Test Code for Steam Heating Solid Fuel Boilers. (ASHVE TRANSACTIONS, Vol. 35, 1929, p. 332.)

[2]ASHVE Standard Code for Testing Stoker-Fired Steam Heating Boilers. (ASHVE TRANSACTIONS, Vol. 44, 1938, p. 366.)

Presented at the 47th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Kansas City, Mo., January, 1941.

[3]*SMA* Uniform Stoker Rating. (Published by *Stoker Manufacturers Association, Coal-Heat,* May, 1938.)

lating bodies in several cities and the unusual requirements occasionally specified for small stoker settings.

In some instances, these setting heights were considerably greater than ordinarily recommended by the industry and the *Stoker Manufacturers Association,* in cooperation with the *Smoke Prevention Association, National Coal Association,* the *Institute of Boiler and Radiator Manufacturers* and the *Steel Heating Boiler Institute,* undertook a careful study of the subject to determine if the established methods of applying this equipment were resulting in satisfactory performance. To assist in this study, an independent research laboratory, the *Battelle Memorial Institute,* Columbus, Ohio, was employed to make an extensive field survey. The results of the field survey have been published in pamphlet form.[4]

After studying the findings of this survey, the *Stoker Manufacturers Association* adopted a uniform recommendation for minimum setting heights. These recommendations represent the combined experience of the manufacturers on many thousands of installations and are published[5] by the *Stoker Manufacturers Association.*

In considering these recommendations, it should be clearly understood that they show merely the average recommended minimum. There are many factors affecting the proper application of stokers to the various types of boilers and furnaces and in many instances, greater or less setting heights may give far better performance than the average values that are shown. They cannot, therefore, be used as arbitrary values in specifying stoker settings.

The wide variation in stoker setting requirements is undoubtedly the reason for so much difference of opinion on this subject, as it is very easy to draw conclusions from experiences on a few unusual installations that do not represent the average condition encountered.

A number of years ago many of the manufacturers of small stokers recommended greater setting heights than have since been found necessary or advisable; in fact, some of these manufacturers have found it necessary to go back and reduce the setting heights on many of these earlier installations in order to obtain satisfactory and practical performance. It is also true, of course, that some installations have given better performance as the result of increasing their setting heights, but on a comparable percentage basis, this number is extremely small.

In concluding this outline of the background for these recommendations adopted by the *Stoker Manufacturers Association,* the writer wishes to emphasize the fact that the data cannot be used arbitrarily for specifying stoker settings with the expectation of obtaining satisfactory results on all installations. They merely represent average requirements that may be varied considerably by the stoker installer based on his experience with the individual equipment, the type of coal that is to be used, and the construction of the boiler or furnace.

Domestic Burners for Pennsylvania Anthracite

Underfeed Type: This commercial standard[6] for domestic anthracite stokers might be considered as an outgrowth of the work that has been carried on for a number of years by the Anthracite Industries Laboratory, Primos, Pa. The general procedure covering its final preparation and presentation to the industry was, however, handled by the Bureau of Standards in its customary manner.

Since the standard was first published in 1934, it has undergone a number of revisions, the latest being November 30, 1940. In its present form, it therefore represents many years of work on the part of the Anthracite Industries Laboratory, the stoker manufacturers, and the Bureau of Standards. Its requirements cover the design, performance, and installation of underfeed type burners using Pennsylvania anthracite as a fuel and having a normal capacity between 10 and 100 lb of coal per hour.

The preparation of this standard for domestic anthracite burning equipment was a much less difficult task, however, than would be that of preparing a similar standard for domestic bituminous stokers. Anthracite coal, as used in this equipment, is more uniform than bituminous coal as to size and burning characteristics and, as a result, anthracite stokers are also far more uniform in design and construction than bituminous stokers.

With the widely different burning characteristics of bituminous coals and the many types of automatic stoker equipment now being used, it would seem extremely difficult at this time to prepare a similar standard for bituminous stoker equipment.

Summary

The writer believes that these codes and standards now existing in the small stoker industry should be of interest and value to many members of the Society, particularly those who may have occasion to specify stoker equipment or have a direct interest in the performance or testing of stoker fired heating equipment.

It is suggested that the Society give consideration to the review of the ASHVE Standard Code for Testing Stoker-Fired Steam-Heating Boilers, giving special attention to a revision of the outline for reporting the heat balance to more clearly show the individual performance of the stoker and boiler.

GLASS BLOCKS INTEREST KANSAS CITY MEMBERS

January 13, 1941. The Kansas City Chapter held its regular meeting at the Hotel President, and according to E. M. Jolley, secretary, the meeting was one of great interest.

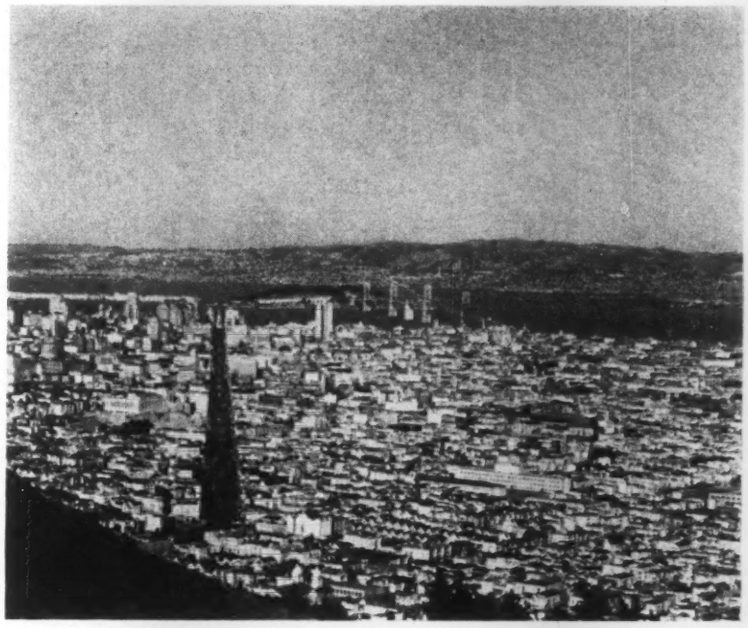
J. C. Kohl, Pittsburgh, Pa., was the first speaker to address the meeting and his phase was on the technical data of glass blocks. S. Frank Cox, Pittsburgh, presented an interesting paper on the subject of insulated windows. Numerous slides were used as illustrations and the members expressed their appreciation to Mr. Cox and Mr. Kohl for their extremely interesting talks. Several of the members decided it was one of the most successful meetings held by the chapter.

[4]Combustion Space Survey and Field Tests, by Sherman, Cross and Ostborg. (Published by *Battelle Memorial Institute.*)

[5]*SMA* Minimum Setting Heights. (Adopted by the *Stoker Manufacturers Association* March 12, 1940.)

[6]Commercial Standard CS48-40, Domestic Burners for Pennsylvania Anthracite (Underfeed Type). (Published March 14, 1934, as Standard CS48-34, revised November 30, 1940, as CS48-40, by the Bureau of Standards, Department of Commerce.)

1941 ASHVE Semi-Annual Meeting Palace Hotel June 16-19



Pacific Heating and Air Conditioning Exposition Civic Auditorium June 16-20

The City of San Francisco from Twin Peaks

San Francisco Awaits You

THE California members are leaving no stone unturned in their preparations to welcome Society members and their friends to the Pacific Coast for the 1941 Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, which will be held June 16-19, with headquarters at the Palace Hotel.

Assisting G. M. Simonson, General Chairman of the Committee on Arrangements, are Clyde Bentley and Dr. B. M. Woods, Vice-Chairmen; also the Committee Chairmen as follows: J. A. Hill, *Reception;* R. A. Folsom, *Transportation;* C. L. Peterson, *Entertainment;* N. H. Peterson, *Banquet;* J. F. Kooistra, *Ladies;* E. W. Simons, *Publicity;* A. J. Bouey, *Finance;* and F. W. Kolb, *Sports.*

Plans are being made to hold a joint session with the *Heating, Piping and Air Conditioning Contractors National Association* on Monday morning, June 16, and this will be followed by a get-together luncheon, after which the opening ceremonies of the Pacific Heating and Air Conditioning Exposition will be conducted at the Civic Auditorium. Among the subjects offered for discussion at the four technical sessions are: panel heating analysis; effect of insulation of heating plant performance; effect of heat transfer on cooling load; and a preview of Society research problems.

An excellent technical program is being arranged by the Meetings Committee, affording an opportunity to discuss many practical technical problems.

A proposed itinerary that will follow a scenic route to San Francisco and permit a selection of accommodations at minimum cost has been arranged. Members from Eastern and Southern points may go by a choice of routes to Chicago, which will be the rendezvous for the trip to San Francisco. The Exposition Flyer, with special ASHVE cars, leaves Union Station, Chicago, June 12, at 12:35 p. m. over the Burlington Route. At Denver those who must hurry to San Francisco will travel via the Moffat Tunnel and the Rockies will be seen in daylight. Arrival in Salt Lake City will be on Friday night, June 13, and the route then follows the Feather River Canyon with arrival at San Francisco at 10:30 p. m. on the 14th.

The train selected will carry special cars for Society members, their families and friends, and provide fast service without extra fare to San Francisco. Standard air conditioned Pullman cars, tourist Pullman equipment, de luxe coaches and dining cars serving all meals will be available.

With these arrangements members and their friends can travel in a body to San Francisco and round-trip tickets will permit diverse routes returning, among which are the following:

1. Via Ogden, Cheyenne, Omaha, Chicago.
2. Via Los Angeles, Grand Canyon, Carlsbad Caverns, Indian Detour, Albuquerque, Wichita, Kansas City and St. Louis or Chicago.
3. Via Los Angeles, Phoenix, El Paso: (a) San Antonio, New Orleans, Atlanta, Washington; or (b) Kansas City and Chicago.
4. Via the North Pacific Coast—Portland, Seattle, Spokane, Yellowstone Park, St. Paul, Chicago.
5. Via the North Pacific Coast—Portland, Seattle, Spokane, Glacier Park, St. Paul, Chicago.
6. Via Portland, Seattle, Victoria, Vancouver, Lake Louise, Banff, St. Paul, Chicago.
7. Via Portland, Seattle, Vancouver, Jasper Park, Winnipeg, St. Paul, Chicago.
8. Via Los Angeles, Boulder Dam, Utah Parks (Bryce-Zion), Salt Lake City, Royal Gorge, Colorado Springs, Denver, Omaha, Chicago.

The Pacific Coast Chapters are planning a series of interesting trips which will extend to Los Angeles, Portland and Seattle, and those attending the meeting can combine their business with pleasure, and enjoy an ideal vacation. San Francisco has all the comfortable temperatures between coolness and warmth, and one can enjoy swimming, yachting, sea fishing, riding, picnicking, golf, boating, camping and trips through the California Redwoods.

It is planned to have notable speakers at the luncheons and banquet, and along with the fine technical papers and various committee meetings, the *HPACCNA* meeting and the Exposition, there should be a great attraction to San Francisco in June, and members should plan now to be there the week of June 16.

The Golden Gate Chapter not only plans to welcome ASHVE members and friends to San Francisco the week of June 16, but is also cooperating with the *Heating, Piping and Air Conditioning Contractors National Association,* which will meet at the St. Francis Hotel.

Those who plan to attend the Semi-Annual Meeting and the *HPACCNA* meeting will also have the opportunity to witness a preview of many noteworthy advances in indoor climate control for human comfort and industrial protection when the heating, ventilating and air conditioning industry convenes in San Francisco for a series of engineering meetings in conjunction with the Pacific Heating and Air Conditioning Exposition, to be held in the Civic Auditorium, June 16-20. According to Charles F. Roth, manager of the Exposition, about three-fourths of the exhibition space offered has already been reserved.

DIRECTOR HOUGHTEN VISITS NORTH CAROLINA

February 20, 1941. The North Carolina Chapter of the Society held its regular monthly meeting in the New Hotel Barringer, Charlotte, and approximately 22 members and guests were in attendance, some of whom travelled over 150 miles.

F. C. Houghten, director of the Society's Research Laboratory, Pittsburgh, delivered an interesting talk on the recent research developments in calculations of solar radiation heat loads in conjunction with estimating cooling requirements. Following Mr. Houghten's address a general round table discussion was held in which practically all present participated. The chapter is looking forward with a great deal of anticipation to a return visit by Mr. Houghten.

The next meeting of the chapter is scheduled for April and will be held in Raleigh, N. C.

PHILADELPHIA HEARS TALK ON AIR CONDITIONING

February 13, 1941. The regular monthly meeting of the Philadelphia Chapter of the Society was held at the Engineers Club, and was called to order at 8:00 p. m. by Pres. C. B. Eastman. The minutes of the previous meeting were read and approved, followed by the report of the treasurer, which was accepted as read. Edwin Elliot, chapter representative for the Hobby Show, called attention to the coming show and urged the members' participation.

President Eastman welcomed J. H. Van Alsburg, Chicago, member of the Society's Committee on Research, and R. A. Wasson, New York, N. Y., who were visiting the Philadelphia Chapter. He then turned the meeting over to H. H. Mather, chairman of the meetings committee, who advised the members that the March meeting would include a visit to the Municipal Court Building, with dinner being served at Hollands.

C. S. Leopold, consulting engineer from Philadelphia, was introduced as the speaker of the evening, and addressed the meeting on the subject of Air Conditioning, which he illustrated with lantern slides. Mr. Leopold gave some interesting data on the details of design and construction of several of his latest and most modern buildings. The talk was well received, and the members were further enlightened by Mr. Leopold's answers to the many questions. The meeting adjourned following the discussion at 9:20 p. m.

ASHVE PAST PRESIDENT ADDRESSES WESTERN NEW YORK

February 10, 1941. The Western New York Chapter of the Society held its regular monthly meeting at the University Club and 32 members and guests were present. Following the reading of the minutes of the January meeting, which were approved as read, B. C. Candee gave a short talk describing his experiences on a trip to California from which he had just returned, and ended by stating that he was very glad to be back.

W. R. Heath, chapter delegate to the Annual Meeting in Kansas City, gave a report on the meeting, and advised the chapter that L. P. Saunders, Lockport, N. Y., former president of the chapter, had been elected to the Council for a three-year term.

W. E. Voisinet announced that the Air Conditioning Council invited the Society to a joint meeting to be held in March, and the invitation was accepted, such meeting to form the regular monthly chapter meeting.

C. W. Farrar suggested that the Buffalo Chapter take immediate action in order to have the 1944 Heating and Ventilating Exposition held in Buffalo in the new Auditorium. A general discussion followed and it was unanimously agreed that Buffalo wanted the 1944 Exposition. President Gifford appointed a committee consisting of Messrs. Farrar, Farnham, Davis, Beman and Commissioner Harding to make necessary arrangements to get this Exposition to Buffalo.

L. A. Harding, Past President of the Society and Commissioner of Public Works of Buffalo, was then introduced and delivered a talk on the Dawn of Science and Invention. The Commissioner gave the Chapter a very interesting talk covering a period of 500 years in history illustrated with slides describing the basic inventions of ancient peoples and traced the rise of these inventions to modern times.

PUBLIC RELATIONS TOPIC AT ONTARIO

February 3, 1941. The regular February meeting of the Ontario Chapter was held at the Royal York Hotel, with 52 members and guests in attendance.

Following dinner at 6:30 p.m. the secretary read the minutes of the preceding meeting, which were accepted as read, and C. Tasker reported on the 47th Annual Meeting of the Society held in Kansas City, which he attended. He pointed out the important research activity now being conducted by the Society, and announced that there were 214 Canadian members.

J. A. Clifton introduced the principal speaker of the evening, Roy D. Kerby, who spoke on Public Relations. Mr. Kirby's address was enthusiastically received. E. R. Gauley expressed a vote of thanks to Mr. Kerby for his splendid address on behalf of the chapter, and this was followed by adjournment.

GOODMAN GUEST AT ILLINOIS

January 13, 1941. The January meeting of the Illinois Chapter of the Society was called to order by Pres. V. L. Sherman with 63 members and guests attending.

The regular order of business included reports of the committee chairmen and the minutes of the December meeting.

President Sherman then called on S. R. Lewis, Chicago, past president of the ASHVE, to introduce the speaker of the evening, William Goodman, consulting engineer, La Crosse, Wis., who spoke on the subject of Dehumidifying Air With Coils. He went back to the fundamentals of the process and traced what occurs on the psychrometric chart, thereby bringing out much information of a practical nature needed in air conditioning engineering. Among the topics covered by Mr. Goodman were the percentage

line on the psychrometric chart, which is determined by the ratio of sensible and latent heat, the importance of selecting the proper coil to give the desired room conditions, and the applications and limitations of reheating and of by-passing air.

His talk, which was of a semi-technical nature illustrated with slides, was well received by the members and in a discussion following, such matters as reheating air with condenser gas by means of the run around cycle, the importance of turbulence in the air stream for heat transfer and the effect of part of the coil surface being dry, were explained. Messrs. Aeberly, Lewis, Locke and others took part in the discussion, which was followed by adjournment.

ILLINOIS DOCTORS DISCUSS COMFORT

December 9, 1940. The December meeting of the Illinois Chapter was called to order by Pres. V. L. Sherman with 60 members and guests attending.

Following the various reports of committee chairmen, President Sherman turned the meeting over to John Howatt, who after a brief introductory talk introduced Dr. Ford K. Hick and Dr. Robert W. Keeton, Department of Medicine, University of Illinois. The workers in the Medical Department of the University, in cooperation with the ASHVE, have been studying the physiological adjustments involved in the loss of heat from the body and the discussion by the speakers covered some of the studies made during the past year.

They explained that the heat of the body is generated largely within the muscles, which are located in the interior of the body, and the heat in excess of requirements for maintenance of body temperature is transported to the surfaces. It was brought out that the mechanism of heat loss from the surfaces depends to a great extent on the character of the environment.

Data illustrative of the results obtained from the studies were shown on lantern slides and a general discussion followed, in which Dr. E. V. Hill and Messrs. Cartland and Adlam took an active part.

TWENTY-THREE YEARS IN INSULATION INDUSTRY

Matthew J. Fitzgerald, secretary-treasurer and general manager of the Standard Asbestos Manufacturing Co., Chicago, has just completed 23 years of service in the asbestos industry, with the belief that Friday the 13th is lucky rather than otherwise. It was on that date in 1917 that he entered the employ of the Standard Asbestos Mfg. Co.

Mr. Fitzgerald was born in Chicago on December 27, 1901, and was educated in the parochial schools there, graduating from De-Paul Academy in June, 1917. He immediately acquired the position as stenographer with the company with which he is still associated and worked his way up to his present position. He is also a director of the company and vice-president and director of Standard Asbestos Mfg. Co., Cleveland, O. He joined the ASHVE in 1934 as a Member, and is a member of the Illinois Athletic Club.

PROF. A. R. ACHESON DIES AT SYRACUSE

Prof. Albert R. Acheson, head of the department of mechanical engineering in the College of Applied Science at Syracuse University, died at his home, 852 Ostrom Avenue, Syracuse, N. Y., on February 25, 1941. Professor Acheson, in his 59th year, had just returned late in January from a vacation in Florida. He was born at Riverton, New Zealand, October 12, 1882, and was graduated from the New Zealand University in 1906, having received the degrees of bachelor of science in mechanical engineering, and bachelor of engineering in electrical engineering.

In his college years he was in the employ of the New Zealand Government Railways during summer vacations and in his later professional years in Syracuse he utilized vacation periods similarly, in practical application of advanced theory and in continuing research.

He came to the United States 35 years ago for technical service with the Westinghouse Electric and Mfg. Co., Pittsburgh, Pa. He became associated with Syracuse University in 1908 as professor of mechanical engineering. His first association with the Westinghouse interests, however, was with the Westinghouse Air Brake Co., Addington, N. Z., in 1904 and 1905. He was with the Wellington and Manawatu Railway Co., in his first post-graduate year.

In his years of identification with the University, he also was associated with civic and municipal activities, and served as a city consultant on gas and electricity from 1914 to 1919, the period in which modern unified street lighting was developed.

He was notable among men of science and foremost as consultant in the field of heating, ventilating and steam generation, serving various industrial and utility clients over a period of 20 years.

In his earlier years he was a leading amateur tennis player competing in local tournaments, and winning the city's double championship with Hubbell West, now of Baldwinsville, as his partner and co-champion. He kept up a participating interest in competitive play. A proficient golfer, he figured in invitational tournaments as often as his engagements permitted. He had an inherited love of outdoor sport, in the British tradition, and enjoyed the speed and flash of American games.

A gifted student as well as teacher, he was referred to fondly among old grads and associates as *"Aitchee."* He was very popular with all his students and held in high regard by the faculty, and considered one of the best teachers Syracuse ever had.

He joined the ASHVE in 1919, taking a keen interest in the work of the Society and contributing much to the advancement of the heating and ventilating profession. He was one of its very active members, serving on various committees from time to time. He was appointed to serve on the Committee to Cooperate with the Rochester School Board in 1926 and 1927.

As Westinghouse Electric and Mfg. Co. industrial engineer, he compiled reports in the summer of 1910 on factory power plants in New York State. The next summer he was operating engineer in charge of the 6,000 hp boiler room of the Utica and Mohawk Valley Railway Co., Utica.

Among his unpublicized consultant services in recent years was work on what has become known